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A REVIEW OF
FOREST INSECT CONTROL AND INVESTIGATIONS
ON THE SIERRA NATIONAL FOREST, 1909 - 1943

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A REVIEW OF

FOREST INSECT CONTROL AND INVESTIGATIONS

ON THE SIERRA NATIONAL FOREST, 1909-1943

FOREWORD

"Bug work" has long been a Forest Service activity on the Sierra. The campaigns to fight bark beetle epidemics date far back into the history of this national forest and have been participated in by a generation of Forest Service employees.

Along with the Forest Service control work, the Bureau of Entomology and Plant Quarantine has conducted a series of studies to improve control methods which also cover a long period of time. All of this work has been duly recorded in an accumulated series of manuscript reports which go to make up the longest continued record of bark beetle control work and investigations in the California region.

Plans have recently been proposed to revise bark beetle detection surveys for the Sierra so that the reporting areas and infestation units will be in line with current management plans. This project gives point to a review of past surveys control work and research. In the mixed conifer stands of the westside type in California are forest insect problems that present a challenge to forest management. Compared with the progress that has been made in the less complex eastside pine type, much still needs to be done along research lines before we will know how best to protect the ponderosa-sugar pine-fir types on the west slopes of the Sierras from the drain of bark beetle losses. These records of the Sierra projects present the best picture that has yet been made available of the behavior of westside infestations. It is proposed in this review to bring this information into condensed form and to give it such interpretation as seems warranted. The material will be treated in three sections covering (1) bark beetle control history, (2) character of bark beetle infestations in the Sierra pine stand and (3) some probable causes of bark beetle epidemics.

I. HISTORY OF BARK BEETLE INVESTIGATIONS AND CONTROL PROJECTS

SIERRA NATIONAL FOREST

by
John M. Miller

The long period of control effort on the Sierra can be attributed not so much to beetle infestations becoming worse on this forest than elsewhere, but to the fact that very soon after the forest was established the personnel undertook to do something about pine beetles. In 1915 E. G. Dudley, writing for the Sierra Ranger, stated "In the absence of St. Patrick we have but two ways in which to rid ourselves of the bark beetles. One is to cut and burn the host trees when harboring the broods and the other is to raise and liberate woodpeckers to feed upon the larvae. The Forest Service, being primarily in the timber business, adopted the first plan."

However, records of pine beetle infestations on the Sierra areas antedate the establishment of the Forest Service. The first record of tree killing by bark beetles was in 1904. In the spring of that year, Dr. A. D. Hopkins, who is known as the father of forest entomology in America, made a trip through the Sierra pine belt. From the end of the railroad at Raymond, he rode the horse-drawn stage to Wawona. Somewhere in that vicinity he came upon a group of large ponderosa pine that had been killed by the western pine beetle. He photographed the group of dead trees and later used this as an illustration in his bulletin on the "Genus Dendroctonus." From Wawona Dr. Hopkins traveled the old Alder Creek trail to Glacier Point and along this route made the first observations of the mountain pine beetle in sugar pine.

In June, 1906, H. E. Burke, of the Bureau of Entomology, was located at Fish Camp and Wawona where he made a great number of observations on bark beetles and other insects of the Sierra. At that time there was a noticeable defoliation of white fir by the fir tussock moth which resulted in widespread top-killing of trees. Burke, however, did not report any epidemic infestations by bark beetles.

Forest Service officers first began to take cognizance of the pine beetle situation in 1909. From that date on down to the present time, reports and records have accumulated which make up continuous annual records of control work, studies and surveys on the Sierra. For the purpose of this report these can best be reviewed through condensed chronological summary.

1909

Bark beetle damage in ponderosa pine was brought to the attention of the Forest Service by Ranger J. M. Miller of the Mariposa district. He reported a slow but apparently general increase of western pine beetle infestation. Infestations in sugar pine by the mountain pine beetle were also noted.

1911

E. G. Dudley, Forest Assistant, was assigned to the Sierra. He took note of the bark beetle infestation and reported more dying trees.

1912

This year the Forest Service inaugurated the procedure of calling on the field force for annual reports of insect infestations. Summarization of the Sierra reports by the Acting Supervisor included an estimate of 1,100 recently killed trees over 16 inches D.B.H.

1913

In January $150 was allotted to the Sierra for insect control work and the "Contour Project" was initiated. It was at first intended to do the greater part of the work with ranger labor, but as the size of the job was realized, more funds were requested and in March the allotment was increased to $1550. The area covered included about 40,000 acres all below the 5000 foot contour extending in a broken belt from Jerseydale to Cascadel. A majority of the trees were infested by Ips confusus and were under 20 inches D.B.H. Although primarily an Ips infestation, Dendroctonus brevicomis was encountered in the larger trees and D. monticolae in sugar pine. During the spring period Ralph Hopping, Forest Examiner, who had been appointed to direct insect control for the regional office of the Forest Service, assisted in the supervision of the Contour project and later made a comprehensive survey of bark beetle conditions throughout the pine belt.

Summary of Control Work - 1913

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Contour	40,000	1,942	705,000	$2,344.00

REPORTS

1. E. G. Dudley. "Insect control, Contour project, Sierra National Forest. January to May, 1913." June 7, 1913

1914

Forest Examiner Hopping recommended continuation of control work on the Contour project in 1914, since an examination in the fall of 1913 revealed that heavy infestations were continuing. This year the work was extended to other areas within the Contour zone. The heaviest infestations were encountered in Blue Canyon, Stevenson Creek and Jose Basin, all south of the San Joaquin river. A small amount of work was done in the Northfork district on private lands to which the Sierra Sugar Pine Lumber Company contributed $317.26. Control work was also initiated in the Chiquito district.

Summary of Control Work - 1914

Project	Acreage	Amount treated Trees	Volume b.f.	Costs
Contour	16,400	2,154	1,203,500	$4,569.09
Chiquito	10,000	405	704,000	2,307.98
Total	26,400	2,559	1,907,500	6,877.07

2. E. G. Dudley. "Insect control, Sierra National Forest, March 10 to May 23, 1914." August 10, 1914

1915

This season the Forest Service continued control work in the Chiquito area where western pine beetle infestations continued active. Work in the Contour area was discontinued. However, work in the sugar pine type to control primarily the mountain pine beetle was carried on by the White and Friant Lumber Company. This private project included some infestation by the western pine beetle in ponderosa pine. Most of the work was done in the Sand Creek and Whiskey Creek drainages north and east of Northfork. Data as to acreage covered and volume treated by the Company were not made available to the Forest Service, or at least cannot be found in the records.

Summary of Control Work - 1915

Project	Acreage	Amount treated Trees	Volume b.f.	Costs
Chiquito	11,640	367	463,000	$2,434.00

3. Ralph Hopping. "Annual report, Insect control, Region 5. F.Y. 1916" November, 1916

1916

There is no record of control work by the Forest Service this year. Ralph Hopping, however, made a survey of the forest and established a series of check plots to determine results of the work carried out the previous year. Plots were located in Blue Canyon, Stevenson Creek and Chiquito. Hopping found increasing infestations in Blue Canyon, Rock Creek and Chiquito and recommended control on these areas for 1917.

It was during this year that a controversy developed between the Forest Service and the Bureau of Entomology over the percentage of infested trees which should be treated in order to secure successful control. Hopping advocated treating 100 percent of the infested trees and re-cleaning of the area for several successive years to pick up any infestation missed in previous work. Dr. A. D. Hopkins of the Bureau of Entomology believed that if a relatively high percent of the infestation or about 75 percent were treated the first year, natural factors of control would take care of the balance within a year or two and that

recleaning would be unnecessary. Hopping's studies of the results of control on the Sierra areas were designed to compare the effects of the 75 and 100 percent treatments. The results were indeterminate and the issue was followed up by the San Joaquin project in 1920-24.

The White and Friant Lumber Company again carried on control work on a fairly large scale in its Sand Creek and Whiskey Creek holdings. This work was started in the spring of 1916, but was continued in the sugar pine type well through the summer. Their burning operations aroused some concern on the part of the Forest Service. This developed into another controversy, this time between Stewart Edward White, a writer of national reputation who was heavily interested in the company, and the Forest Service. The issue was over the effects of light burning upon bark beetle infestations. Mr. White published a series of articles in which he advocated burning of forest floor and understory as a method of beetle control and attributed the development of recent bark beetle epidemics to the Forest Service's policy of total fire exclusion. Both the light burning and the percentage controversies of this period centered around the insect control activities on the Sierra.

4. Ralph Hopping. "Annual report, Insect Control, Region 5. F.Y. 1917." November, 1917

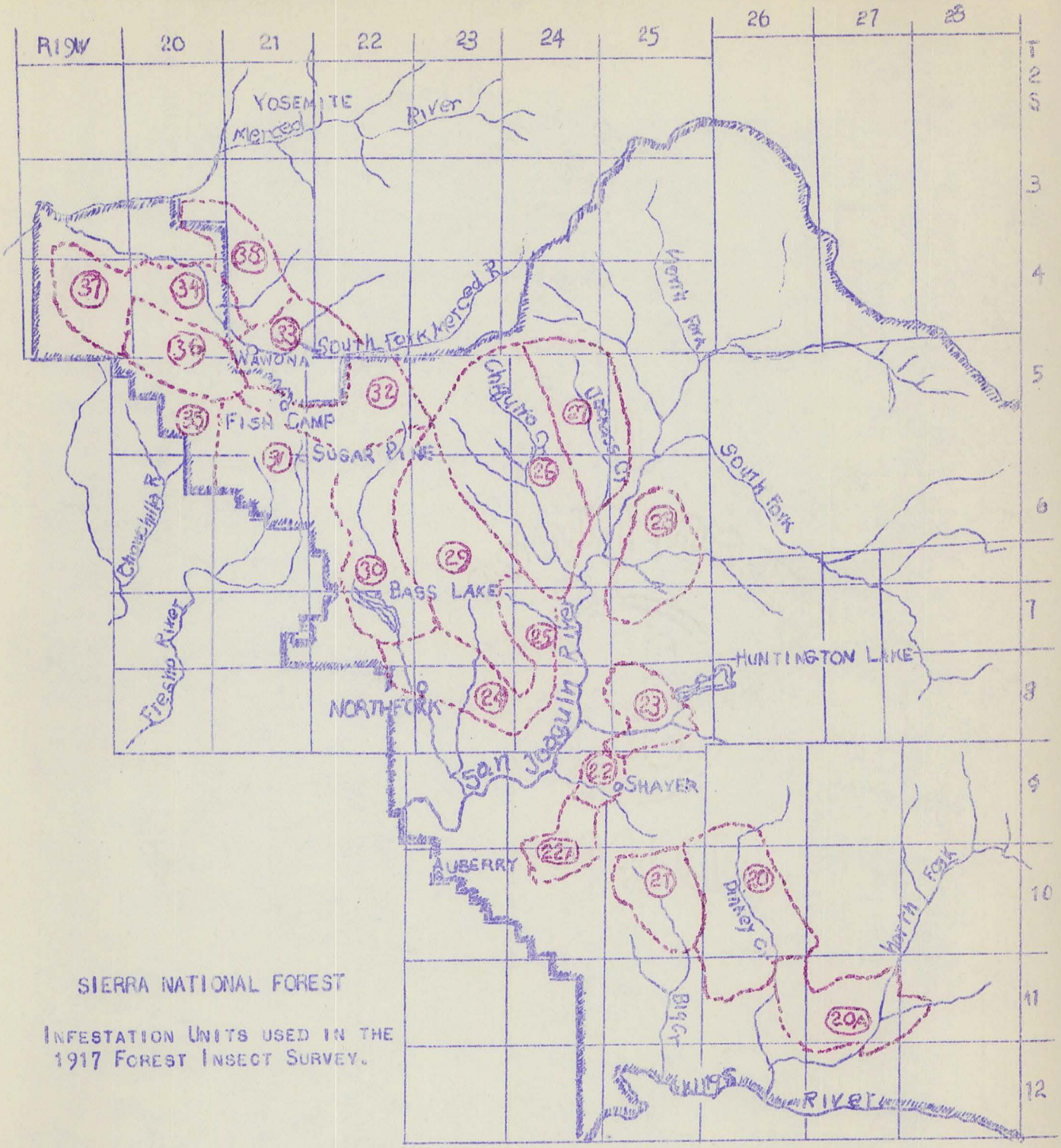
5. "Inspection Report. Stevenson Creek Project." Nov. 4, 1916

6. Stewart Edward White. "Tree-killing beetles of California and possible remedies." American Lumberman, Dec. 9, 1916

1917

This year was marked by the largest insect control campaign in the pine type that had been undertaken up to this time. The White and Friant Lumber Company set up their operation this year in cooperation with the Forest Service. The company carried on the work in the Sand and Whiskey Creek tract, the Forest Service contributing for the cost of work that was done on National Forest land. The Forest Service conducted its own operations in Blue Canyon, Rock Creek and Chiquito.

During the summer of 1917 the Forest Service in cooperation with the Bureau of Entomology conducted a comprehensive survey of bark beetle conditions throughout the California pine areas. This undertaking was also participated in by a number of private timber holding companies. The purpose of the survey was to appraise the timber losses that were occurring and to recommend control where necessary. The Sierra survey was carried out by Hopping, Miller and Jaenicke. The pine belt of this National Forest was estimated at 316,000 acres which was divided into 21 separate infestation units. The total losses for the season of 1917 were estimated at 3,380,000 board feet of ponderosa pine and 5,099,000 board feet of sugar pine. The infestation was considered to be epidemic on 18 of the 21 units and a control program was recommended, estimated to cost $29,600.



SIERRA NATIONAL FOREST

INFESTATION UNITS USED IN THE 1917 FOREST INSECT SURVEY.

20	DINKEY
20A	PATTERSON MOUNTAIN
21	BLUE CANYON
22	STEVENSON CREEK
23	BIG CREEK
24	HOGUE RANCH
25	ROCK CREEK
26	CHIQUITO
27	JACKASS
28	DALTON
29	SAND AND WHISKEY CREEKS
30	WILLOW CREEK
31	FRESNO RIVER
32	MT. RAYMOND
33	WAWONA
34	IRON MOUNTAIN
35	CHOWCHILLA
36	SIGNAL PEAK
37	MARIPOSA
38	ALDER CREEK

Summary of Control Work - 1917

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Blue Canyon	12,600	287	380,000	1,515.58
Rock Creek	5,920	113	169,000	912.93
Chiquito	13,600	526	585,800	2,492.28
Sand & Whiskey Cr.	24,500	701	2,107,200	6,911.91
Total	56,620	1,627	3,242,000	$11,832.70

7. Ralph Hopping. "Annual report, Insect Control, Region 5. Season of 1917."

8. A. J. Jaenicke. "Forest insect survey of the Sierra National Forest, Summer of 1917." January, 1918

9. Stewart Edward White. "Surface Burning." American Lumberman. Mar.10, 1917

1918

The impact of World War I apparently affected the Forest Service program this season as no control work was undertaken. The White and Friant Lumber Company, however, continued with control into its own holdings, working mostly on the treatment of sugar pine in its Whiskey Creek tract.

10. Ralph Hopping. "Annual report, Insect Control, Region 5. Season of 1918." November, 1918

1919

This was apparently a season during which no control work or surveys were undertaken anywhere on the forest. However, there were developments during the year which had a direct bearing on future control activities on this forest. In order to obtain information which would settle the controversial percentage principle and to carry on experimental work to develop better control methods and strategy, Hopping, Pearce and Jaenicke of the Forest Service, and Miller, Evenden and Patterson of the Bureau of Entomology developed what was titled the "Ashland Conference Plan."

The recommendations of this conference proposed a five year program of control work on ten of the 1917 survey units of the San Joaquin watershed, including some 130,000 acres of the mixed conifer types. The plan called for an initial treatment of all ten units to reduce epidemic infestations; and for subsequent maintenance work on selected units over a period of four years. The experimental phases of the project called for a test of summer control work using the solar heat method; and the working of different units with varying intensity to determine the percentage of treatment which would give the best return for the effort expended. Ralph Hopping who had been in charge of insect control in Region 5 since 1913 resigned at the end of this year to accept a position with the Canadian government.

11. J. M. Miller, Ralph Hopping, et al. "Recommendations of the Third Annual Ashland Conference." November, 1919

1920

The program of the San Joaquin project was initiated in February of this year. In order to supervise the experimental phases, the Bureau of Entomology established a field station at Northfork and assigned J. M. Miller and Albert Wagner to the project. The control work was performed in two periods, February 26 - May 27, during which only the burning method was used and June 15 to December 1, during which the solar heat method was used supplemented by burning when conditions permitted.

It was found that the solar heat method of treatment was applicable to trees in exposed places during June, July and August. The units covered by control were Northfork, Hogue Ranch, Rock Creek, Chiquito, Dalton, Sand and Whiskey Creek and Crane Valley. The other units, Stevenson Creek, Jose Basin and Big Creek - all south of the San Joaquin River, were reserved as check areas.

Summary of Control Work - 1920

Project	Acreage	Spp.	Amount treated: Trees	Amount treated: Volume b.f.	Costs
San Joaquin	95,000	PP	655	1,042,000	
		SP	73	262,960	
Total	95,000	PP-SP	728	1,304,960	$7,135.06

12. J. M. Miller. "Working plan, San Joaquin insect control project, 1920-1924." June 1, 1920

13. "First annual report, San Joaquin insect control project, Sierra National Forest." May, 1921

1921

Only summer maintenance control work was carried on this year in the same units treated in 1920. The Sugar Pine Lumber Company cooperated in the Sand and Whiskey Creek Unit, contributing $447.22 for treatment of trees on its own lands. The work on standing infested trees was concentrated only where the infestation was most active. Trap trees were tried out and a considerable volume of windfalls were treated. About 10 percent of the total infestation was in sugar pine.

In July F. P. Keen joined the Bureau of Entomology staff and worked on the San Joaquin for the greater part of this season. In December he was transferred to the Southern Oregon-Northern California project at Klamath Falls.

Summary of Control Work - 1921

Project	Acreage	Amount treated: Trees	Amount treated: Volume b.f.	Costs
San Joaquin	95,000	462	694,470	$3,709.07

14. J. M. Miller. "Progress report, San Joaquin Project." April, 1923

1922

The results of the 1921 control work indicated that treatment of trap trees was ineffective in holding the infestation which appeared to be gaining by the end of this season. It was considered that more intensive work would have to be done to prove or disprove the efficacy of maintenance control methods. In order to keep within the cost limitations, it was decided that the experimental phases of the project would be better served if the work was concentrated upon a smaller area. A revised working plan was submitted and adopted at the beginning of this season, which proposed that the summer control work be continued, but limited to the Chiquito basin units. Six sub-units covering 23,000 acres were set up in which the following treatments were tried out for different units:

(1) Spring control work only - Arnold and Dalton units
(2) Combined spring and summer control work without trap trees - West Chiquito
(3) Combined spring and summer work with trap trees - Logan unit
(4) Complete extermination by combined spring and summer work - Forked Meadow unit
(5) Loss cruises without control work to test the effect of natural control factors - Jackass unit

Earl Morrow was added to the staff of the Bureau of Entomology and supervised operations in the Chiquito.

Summary of Control Work - 1922

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
San Joaquin	23,440	459	420,230	$3,062.26

15. J. M. Miller. "Revised Working Plan, Season of 1922, San Joaquin insect control project." April 26, 1922

"Progress report, San Joaquin project." April, 1923

1923

Control work was continued this year under the revised working plan of 1922. The technical personnel on the project was increased by the assignment of H. L. Person as Junior Entomologist. The use of trap trees was discontinued entirely this year, since results of the preceding season demonstrated that their expense and ineffectiveness did not warrant their use. Spring control work was discontinued on the Dalton unit, but the Logan, Forked Meadow, West Chiquito and Arnold units were worked under the methods assigned in 1922.

Summary of Control Work - 1923

Project	Acreage	Amount treated Trees	Volume b.f.	Costs
San Joaquin	19,120	416	567,650	$3,831.90

17. H. L. Person. "Second Progress report, San Joaquin project." Apr. 9, 1924

18. J. M. Miller. "The use of trap trees in the control of the western pine beetle." November 18, 1924

1924

The experimental program of this year was continued on the same units as in 1923 until September 1. The volume of infestation treated, however, was considerably less than in 1923. In addition to this experimental work in the Chiquito units, the Sugar Pine Lumber Company entered into an agreement with the Forest Service to treat an area in the Whiskey Creek drainage, due to an increasing infestation in sugar pine. This work was carried out in May, 1924.

The final results of the San Joaquin project were summarized and a report submitted covering the five-year program. The conclusions reached were: (1) that continued maintenance control, regardless of the percentage of infestation treated, increased in cost and decreased in comparative effectiveness as the infestation decreased; under very low endemic conditions, maintenance control is not warranted economically unless the treated trees are utilized.

(2) That treatment of 100 percent of the infestation on a limited area each year does not "exterminate" the beetles and is impracticable.

(3) That when bark beetle infestations are endemic, the natural factors of control are fully as potent as direct control work and these factors should be thoroughly studied before further maintenance control is recommended.

Summary of Control Work - 1924

Project	Acreage	Spp.	Amount treated Trees	Volume b.f.	Costs
San Joaquin	19,120	PP	137	182,970	1,579.33
Whiskey Creek	9,600	PP	8	25,600	848.75
		SP	46	340,510	
Total	28,720	PP-SP	191	549,080	$2,428.08

19. J. M. Miller. "Third Progress report, San Joaquin project, Sierra N.F." December 10, 1924

20. "Control of the western pine beetle on the San Joaquin project." December 20, 1924

21. J. M. Miller. "Cooperative insect control, Whiskey Creek tract - Sierra N. F., Season of 1924." May 30, 1924. (Discusses cooperation with the Sugar Pine Lbr. Co.)

22. H. L. Person. "Chilkoot Road-Slash Study." December 18, 1924

1925

In line with the recommendations of the San Joaquin project, the work on this forest was shifted from direct control to a study of the natural factors involved in maintenance control. H. L. Person began a series of studies of biological control at a field base located at Cascadel, California; J. M. Miller initiated a study of the relation of fire injury to bark beetle infestations on the Northfork burn.

23. J. M. Miller. "Western pine beetle studies and experiments, Cascadel Unit, Northfork, California. Season of 1925." June 28, 1926.

24. "Western pine beetle flight study, San Joaquin project, 1924." June, 1927.

25. "Oat Mountain flight experiment, San Joaquin project, 1925." April, 1928.

26. "Results of the 1924 insect control work on the Whiskey Creek tract, Season of 1924." February 11, 1926.

1926

Only experimental work and studies were continued this season at Cascadel. Person concentrated attention on predators of the western pine beetle.

27. H. L. Person. "Report of western pine beetle studies, Cascadel Unit. Season of 1926." March 14, 1927.

1927

Biological studies and investigative work on fire-insect relationships were continued from the Cascadel field base; no control work was undertaken.

28. H. L. Person. "Report on western pine beetle studies of 1927, Cascadel Unit, Northfork, California." May 28, 1928.

29. J. M. Miller. "Preliminary report, Northfork Burn study." May, 1927.

1928

This year the Bureau of Entomology moved its biological studies into Northern California because of highly epidemic infestations in the Modoc areas. On the Sierra a final check was made of conditions on the Northfork burn.

30. J. M. Miller. "Final report, Northfork Burn study." March 28, 1929

1929

No extensive surveys, control work or investigations were conducted on the Sierra this year. General observations and one small check plot at Cascadel indicated that following the drought year of 1924, there had been a slight increase of beetle infestations in 1925 which subsided to a low point again in 1929.

1930

Again no surveys were made this season, but from records secured in 1931 it was found that Ips and western pine beetle infestations began an aggressive increase during the later summer of 1930.

1931

This year marks the beginning of the regional survey system of plots and detection surveys in the pine belt which have been continued annually up to the present time. In July K. A. Salman and the Bureau of Entomology crew established Regional Survey plot No. 7 in the Cascadel basin, Nos. 8 and 9 in Chiquito, No. 12 at Fence Meadow and No. 13 in Blue Canyon. Each of the sample plots contained 320 acres of timber type.

The bark beetle infestations during the late 1931 season were highly aggressive. Spectacular outbreaks of top-killing by Ips beetles followed by western pine beetle infestations in the lower boles appeared in large groups throughout the lower ponderosa pine belt. The more important centers were located around Bass Lake, Cascadel, Pine Ridge and Blue Canyon. Much of this active infestation centered around the borders of the sugar pine sale area where logging operations had closed down during the season.

When the extent of this situation was realized, a large scale control operation was recommended and approved to protect the remaining timber values on the sale area. This was termed the Sugar Pine Sale project. Work was started November 1 on the Cascadel and Rock Creek units and continued until it was closed down by storms in early December.

Summary of Control Work - 1931 (Fall period)

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Cascadel	5,450	421	490,000	4,092.12
Rock Creek	2,262	222	487,000	4,034.63
Total	7,712	643	977,000	$8,126.75

31. J. M. Miller. "Insect control - Sierra National Forest, November, 1931 - March, 1932." October, 1931

32. Carl A. Gustafson. "Insect control report, Sierra National Forest. Fall Period, 1931." January, 1932

1932

As soon as the control areas were open, work was resumed in the spring of this season. The first control camps were opened on March 20 in Cascadel and Rock Creek; by April 15 a camp was opened in Chiquito; the work closed down May 5. The area covered was practically a continuous belt of the ponderosa pine type extending from Northfork through the Cascadel, Saginaw, Ross Creek, Fish Creek, Rock Creek watersheds and the Chiquito basin.

Summary of Control Work - 1932 (Spring period)

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Cascadel	6,630	1,111	1,477,000	
Rock Creek	3,080	377	568,000	
Chiquito	9,600	602	1,073,000	
Totals*	19,310	2,090	3,118,000	$15,543.00

*Not including fall work of 1931

Surveys in the fall of 1932 revealed that infestations in Blue Canyon which had not been controlled in the 1932 spring control program, had invaded the better site timber of the ponderosa-sugar pine type in the Dinkey-Fence Meadow area. A high percent of the infestation was in sugar pine. Control recommendations were made that this be worked in the spring of 1933.

The intense activity of bark beetles in the Sierra areas convinced the Bureau of Entomology that studies should be resumed in the ponderosa-sugar pine type of the westside. With the cooperation of the Forest Service, a small laboratory was constructed at Bass Lake. G. R. Struble, with an assistant, was assigned to control experiments and biological studies to improve control methods. Tests were started with penetrating oil sprays on infested trees and experiments were carried out with injection of chemicals into the sap stream

33. Carl A. Gustafson. "Insect control report, Sierra N.F., California; Chiquito-Rock Cree-Cascadel Areas." July 15, 1932

34. G. R. Struble. "Cascadel Tree Selection Plot: Study of Losses and Applications of tree selection theory." May 11, 1932

1933

Fence Meadow Project

The problem that confronted the forest in the spring of 1933 was to get the control work started at Fence Meadow. The winter had left an unusually heavy snow pack and roads were blocked to truck transportation. By using bull-dozer equipment, the road across Blue Canyon was made passable by March 20. In discussing this project Forest Supervisor Benedict wrote to the Regional Forester, "This was the largest control job we ever had and because of adverse weather and road conditions, the toughest. We threw into the job practically every man we had; District Rangers, Fire chief, technical men and road organization." The control at Fence Meadow was carried through rapidly once the area was reached and was completed May 4. The Southern California Edison Company which owned about 50 percent of the timber in the Fence Meadow Area contributed $5000 as a cooperative fund to meet costs.

Sugar Pine Sale Project

A second working of the Sugar Pine sale project was also carried through. This was started with fall work in 1932 and completed the following spring. The periods of work were from November 28-December 17, 1932, and from March 17-May 7, 1933. All of the areas worked the preceding season were recleaned and some additional acreage was covered.

Bass Lake Project

With the completion of these two projects in May, 1933, the Forest embarked on a program of summer control work. The advent of the CCC program made available the manpower to undertake control where it had not been previously possible. The Bass Lake area, where there had been a heavy uncontrolled infestation, was selected for summer work which was started in June. Solar heat was used as a method of control.

Dinkey Project

Reworking and extension of the control area of the Fence Meadow project was decided upon for the fall of 1933. Developments in the use of penetrative oil sprays offered possibilities in the use of this method. It was decided to give it a try out in this fall program. The working period extended from October 16 to November 16. Most of the work was done in the Dinkey unit just north of the Fence Meadow area.

Summary of Control Work - 1933

Project	Acreage	Spp.	Amount treated: Trees	Amount treated: Volume b.f.	Costs
Sugar Pine Sale	21,379	PP	2,258	2,828,800	9,050.00
		SP	332	1,400,200	
Fence Meadow	11,092	PP	1,013	1,914,810	9,705.00
		SP	425	2,418,050	
Dinkey Unit	12,300	PP	62	163,740	2,512.11
		SP	80	577,800	
Bass Lake	9,000	PP	588	715,220	
		SP	6	43,650	
Total	54,771	PP	3,921	5,622,570	$21,267.11
		SP	843	4,439,700	

The amount of control and experimental work accomplished in 1933 is reflected by the number of reports.

35. Carl A. Gustafson. "Insect control, Sierra N.F.; Fence Meadow and Sugar Pine Sale Project." July 5, 1933

36. Crawford B. Buell. "Insect control, Sierra N.F.; Fence Meadow Project (Dinkey Unit)." December 1, 1933

37. G. R. Struble. "Report on CCC insect control, Bass Lake project, Sierra N.F." January 30, 1934

38. "Reduction of ponderosa pine stands on the Bass Lake area by western pine beetle epidemic, 1931-33." March 5, 1934.

39. "Results of oil-treated ponderosa pine infested by D. brevicomis and Melanophila gentilis." Dec. 13, 1933

40. "Summary of results, Dinkey oil control project, 1933." March 5, 1934

1934

The insect control program for this season was almost entirely maintenance, following up the heavy work done the previous year.

Fence Meadow Project

It was found that the penetrative oil treatment tried out on this area in the fall of 1933 was unsatisfactory as a whole, although it was successful in some thin barked trees where there was optimum temperature conditions. Struble found that it did not "cause enough kill of broods on the average tree to warrant recommendation in the event of further control work." Consequently, it was decided to follow up the 1933 control work with maintenance under the regular method of burning the infested bark. This program was carried out during the period from March 9-29, 1934.

Bass Lake, Cascadel, Saginaw

The treatment of any infested trees on these accessible units was carried out as a winter program by CCC labor. The working period was from January 8-21, 1934. Some later work was was at Bass Lake in late May.

El Portal, Rush Creek, Bishop Creek

An intensive insect control campaign was carried out by the Yosemite National Park in 1933 and 1934. In the spring of 1934 the Park organization treated trees on national forest lands adjoining the Park boundaries in order to secure a protected boundary. Under agreement, the Sierra reimbursed the Park Service for this work.

Summary of Control Work - 1934

Project	Acreage	Spp.	Amount treated: Trees	Amount treated: Volume b.f.	Costs
Fence Meadow	11,392	PP	215	352,930	2,317.54
		SP	90	591,670	
Bass Lake, etc.	7,380	PP	198	98,030	*
El Portal, etc.	3,609	PP	157	360,950	1,442.99
Total	22,381	PP	570	811,910	$3,760.53
		SP	90	591,670	

*No data, work by CCC

41. J. K. Munhall. "Insect control, Fence Meadow Project." May 21, 1934

42. G. R. Struble. "Report on ECW insect control, Cascadel and Saginaw maintenance project, Sierra N. F." January 31, 1934

43. "The Mountain pine beetle in sugar pine, Season of 1933." March 1, 1934

44. Emil Ernst. "Report on insect control, Spring 1934. Yosemite National Park." July 9, 1934

1935

Maintenance work was continued in the lower ponderosa pine belt by CCC crews and other relief organizations as a fall and winter program. A fairly active infestation was found in Hugh Ryan Canyon. The working period extended from November 20, 1934, to May 3, 1935. No regular funds were used and costs can be summarized only on a man-day basis.

Summary of Control Work - 1935

Project	Acreage	Amount treated: Trees	Amount treated: Volume b.f.	Costs
Redwood, Lewis, Carter & Peterson Creeks	3,970	453	547,640	*
Willow Cr.(Bass Lk.)	3,930	*		*
Hugh Ryan Canyon	4,080	285	634,990	*
Total	11,980	738	1,182,630	

*No data, work by CCC

An annual forest insect survey of the Sierra was initiated this season by the Bureau of Entomology and Plant Quarantine. This activity and the annual report to the Forest Supervisor have been continued each season up to 1943.

45. Burt Hurt. "Bug work, Sierra National Forest. Winter of 1934-35." March 1, 1935

46. J. M. Buck. "Insect control, Hugh Ryan Canyon, 1935." Nov. 16, 1935

47. G. R. Struble. "The Mountain pine beetle in sugar pine. Season of 1934." January, 1935.

48. G. R. Struble and George Hensill. "Oil control experiments against Dendroctonus brevicomis, Dendroctonus monticolae and Flatheads." January 8, 1935

49. J. E. Patterson "Forest insect survey, Sierra N. F., Season of 1935." December 18, 1935

50. G. R. Struble. "Seasonal history and habits of Dendroctonus monticolae in the Central Sierra Nevada Region, Season of 1935." January 31, 1936.

Again maintenance control was carried out in areas where there appeared to have been more than normal activity of the beetles. That increases were developing was indicated, particularly at Fence Meadow, by Patterson's survey in the late fall of 1935. Six areas were worked, Fence Meadow, Cascadel, Bass Lake, Batterson, Hugh Ryan and the Harris Ranch Burn. Various types of labor were used on these projects, including ERA-CCC and California Edison Company cooperative fund. The period of work extended from March 16 to April 11, 1936.

Summary of Control Work - 1936

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Fence Meadow	2,500	123	158,930	1,390.28
Cascadel	2,180	83	92,210	370.07
Base Lake	7,560	465	484,430	1,342.79
Total	12,240	671	735,570	$3,103.14

51. M. A. Benedict. "Annual report on insect control work, Sierra N. F., Season of 1936." October 23, 1936.

52. J. E. Patterson "Forest insect survey, Sierra N. F., Season of 1936." January 23, 1937.

53. "Bark beetle infestations in Harris Ranch Burn - Memo to Forest Supervisor, Sierra National Forest." December 15, 1936.

1937

A new phase of insect control was introduced this season through the treatment of infestation on cutover areas. Following a windfall during the winter of 1935-36, the mountain pine beetle infestation began increasing in reserve stands of the Signal Peak area. By the spring of 1937 losses of sugar pine trees were becoming serious and control work was undertaken. This was carried out as a summer control project, using the solar heat method of control with a three-man crew from the WPA Blister Rust control camp. The period of work was from August 17 to September 3, with the following results: Acreage covered - 1,650, Costs - 36 man-days, Trees treated - 16, Volume treated - 40,120 board feet.

In the fall of 1937 the Bureau of Entomology and Plant Quarantine received an authorization to construct a permanent forest insect laboratory to be maintained as a center of investigations and surveys for westside Sierra conditions. Through cooperation of the forest, the laboratory was constructed by CCC labor. The site selected was at the Miami Ranger Station. The buildings were started in the fall of 1937 and completed and occupied the following spring.

No other control work was undertaken this season.

54. G. R. Struble. "Signal Peak insect control project, Sierra N. F., 1937." November 5, 1937.

1938

Maintenance work was again carried out in the ponderosa pine belt. CCC, SRA and cooperative funds were used. This was a spring operation extending from March 15 - May 3. All trees treated were ponderosa pine.

Summary of Control Work - 1938

Project	Acreage	Amount treated: Trees	Amount treated: Volume b.f.	Costs
Lewis Creek	780	124	22,500	37.00
Bass Lake	2,500	226	33,700	224.62
Whiskey, Ross, Rock Creeks	3,500	42	39,560	306.27
Total	6,780	392	95,760	$567.89

55. J. M. Buck. "Insect control, Sierra N. F., Spring of 1938." June 22, 1938

56. S. T. Carlson. "Forest insect survey, Sierra N. F., Season of 1937-38." October 21, 1938

1939

"During the summer of 1938 there was a small build-up of insects and more brood trees were noted during the winter. A very mild winter allowed strong broods to form and the control work was deemed necessary. There was quite a flare-up in the town of Big Creek and surrounding territory. No insect control funds were expended with the exception of a small amount of Southern California Edison money." From report by M. A. Benedict (57).

Summary of Control Work - 1939

Project	Acreage	Amount treated: Trees	Amount treated: Volume b.f.	Costs
Bass Lake	10,440	95	62,522	480.64
Hogue Ranch	2,720	60	90,000	168.00
Big Creek	6,400	50	101,540	175.43
Total	19,560	205	254,062	$824.07

57. M. A. Benedict. "Insect control, Sierra N.F., Season of 1939." Report to Regional Forester. May 22, 1939.

58. S. T. Carlson. "1939 Forest insect survey, Sierra N. F." Dec. 12, 1939

59. G. R. Struble. "D. monticolae infestation in Sugar Pine - Fish Creek Drainage, Sierra N. F." September 18, 1936

1940

Endemic conditions prevailed generally throughout the forest this year, except in the vicinity of Fence Meadow where a local increase was reported in the 1939 survey. Control work was undertaken during the spring to reduce the infestation in sugar pine and ponderosa pine. In addition, maintenance control was carried on in several other areas.

Summary of Control Work - 1940

Project	Acreage	Amount treated Trees	Volume b.f.	Costs
Fence Meadow and Big Creek	16,960	245	751,000	3,061.63
Fish Creek	2,400	21	101,000	449.00
Bass, Lk, Batterson	10,000	83	19,000	275.50
Soquel	1,575	25	50,000	247.00
Cascadel	4,800	18	26,000	150.00
Total	35,735	392	947,000	$4,183.13

60. J. E. Patterson. "Forest insect survey, Sierra N. F., Season of 1940." November 7, 1940

61. C. E. Dunston. "Annual report, Calendar Year 1940, Region 5." March 26, 1941

62. G. R. Struble. "The Bass Lake Study Area." November 6, 1940

1941

Insect activity was generally low over the forest as a whole. One exception was the flare-up of an aggressive local infestation in sugar pine and ponderosa pine at Shaver Lake and Big Creek. Some maintenance work was done here in 1940, but lack of funds prevented the completion of that job. An adequate allotment of cooperative money (P.&M. and California Edison Company and CCC) was secured to carry out the control of this infestation in the spring of 1941. Maintenance control was also carried out by CCC in the Bass Lake and Ross Creek areas.

Summary of Control Work - 1941

Project	Acreage	Amount treated Trees	Volume b.f.	Costs
Shaver Lk.-Big Cr.	12,200	226	241,980	2,088.08
Northfork-Bass Lk.	2,220	44	9,500	105.30
Ross Cr.-Hooker's Cove	6,400	17	36,420	150.75
Total	20,820	287	287,900	$2,344.13

63. J. E. Patterson "Forest insect survey, Sierra N. F., Season of 1941." October 30, 1941

64. C. E. Dunston. "Annual report, Calendar Year 1941, Region 5." Mar. 26, 1942

65. G. R. Struble. "Insect control, Big Creek Area, Sierra N.F." Memo to Forest Supervisor. March 17, 1941

66. "Losses in sugar pine on cutover areas due to the mountain pine beetle, Signal Peak Unit, Sierra N.F." Apr. 22, 1941

1942

The Shaver Lake area again showed active infestations in sugar pine, necessitating a maintenance control program. Funds were provided by the Forest Service and the California Edison Company and the area was again worked during the spring period.

Summary of Control Work - 1942

Project	Acreage	Amount treated		Costs
		Trees	Volume b.f.	
Shaver Lake	12,000	185	443,690	-

67. J. E. Patterson and G. R. Struble. "Forest insect survey, Sierra N. F., Season of 1942." February 15, 1943

68. G. R. Struble. "Cascadel tree selection plot - a study of tree selection by the western pine beetle. Final report." Apr. 10, 1942

69. J. M. Miller. "Interrelations of insects and fires - Supplementary report, Northfork Burn study." February 15, 1943

Tabulation of Bark Beetle Control, Sierra National Forest, 1913-1942

Year	Project	Acreage	Spp.	Amount treated: Trees	Amount treated: Volume b.f.	Costs: Total	Costs: per tree	Costs: per Mbm
1913	Contour	40,000		1,942	705,000	$2,344.00	$1.20	$3.32
1914	Contour	16,400		2,154	1,203,500	4,569.09	2.12	3.79
	Chiquito	10,000		405	704,000	2,307.98	5.70	3.28
	Total	26,400		2,559	1,907,500	6,877.07	2.74	3.66
1915	Chiquito	11,640		367	463,000	2,434.00	6.63	5.26
1916	-							
1917	Blue Canyon	12,600		287	380,000	1,515.58		3.98
	Rock Creek	5,920		113	169,000	912.93		5.40
	Chiquito	13,600		526	585,800	2,492.28		4.25
	Sand & Whiskey Creek	24,500		701	2,107,200	6,911.91		3.28
	Total	56,620		1,627	3,242,000	11,832.70		4.23
1918	-							
1919	-							
1920	San Joaquin	95,000	PP	655	1,042,000	7,135.06		
			SP	73	262,960			
	Total	95,000	PP-SP	728	1,304,960	7,135.06	9.80	5.46
1921	San Joaquin	95,000		462	694,470	3,709.07	8.03	5.33
1922	San Joaquin	23,440		459	420,230	3,062.26	6.71	7.25
1923	San Joaquin	19,120		416	567,650	3,831.90	9.35	6.75
1924	San Joaquin	19,120	PP	137	182,970	1,579.33	11.52	8.63
	Whiskey Creek	9,600	PP	8	25,600	848.75	15.72	2.32
			SP	46	340,510			
	Total	28,720	PP-SP	191	549,080	2,428.08	13.62	5.48
1925	-							
1926	-							
1927	-							
1928	-							
1929	-							
1930	-							
1931	Cascadel	5,450		421	490,000	4,092.12	6.01	5.17
	Rock Creek	2,262		222	487,000	4,034.63	10.13	5.73
	Total	7,712		643	977,000	8,126.75	8.07	5.45
1932 (Spr. per.)*	Cascadel	6,630		1,111	1,477,000	-	3.44	2.54
	Rock Creek	3,080		377	568,000	-	6.04	3.45
	Chiquito	9,600		602	1,073,000	-	4.49	2.52
	Total	19,310		2,090	3,118,000	15,543.00	4.66	2.84

*Does not include fall work of 1931

Tabulation of Bark Beetle Control (continued)

Year	Project	Acreage	Spp.	Amount treated: Trees	Amount treated: Volume b.f.	Costs: Total	Costs: per tree	Costs: per Mbm
1933	Sugar Pine Sale	21,379	PP	2,258	2,828,800	9,050.00	3.48	2.14
			SP	332	1,400,200			
	Fence Meadow	11,092	PP	1,013	1,914,810	9,705.00	6.76	2.24
			SP	425	2,418,050			
	Dinkey Unit	12,300	PP	62	163,740	2,512.11	17.69	3.39
			SP	80	577,800			
	Bass Lake	9,000	PP	588	715,220	*		
			SP	6	43,650			
	Total	54,771	PP	3,921	5,622,570			
			SP	843	4,439,700			
1934	Fence Meadow	11,392	PP	215	352,930	2,317.54	7.60	2.45
			SP	90	591,670			
	Bass Lake, etc.	7,380	PP	198	98,030	*		
	El Portal, etc.	3,609	PP	157	360,950	1,442.99	9.19	4.00
	Total	22,381	PP	570	811,910	3,760.53	8.54	3.61
			SP	90	591,670			
1935	Redwood, Lewis, Carter & Peterson Creeks	3,970		453	547,640	*		
	Willow Cr.(Bass Lake)	3,930		*		*		
	Hugh Ryan Cny.	4,080		285	634,990	*		
	Total	11,980		738	1,182,630			
1936	Fence Meadow	2,500		123	158,930	1,390.28	10.69	8.74
	Cascadel	2,180		83	92,210	370.07	4.45	4.02
	Bass Lake	7,560		465	484,430	1,342.79	2.84	2.77
	Total	12,240		671	735,570	3,103.14	4.61	4.35
1937	-							
1938	Lewis Creek	780		124	22,500	37.00	.28	1.17
	Bass Lake	2,500		226	33,700	224.62	.99	6.66
	Whiskey, Ross, Rock Creeks	3,500		42	39,560	306.27	7.29	7.66
	Total	6,780		392	95,760	567.89	1.45	5.91
1939	Bass Lake	10,440		95	62,522	480.64		
	Hogue Ranch	2,720		60	90,000	168.00		
	Big Creek	6,400		50	101,540	175.43		
	Total	19,560		205	254,062	824.07	4.00	3.24
1940	Fence Meadow & Big Creek	16,960		245	751,000	3,061.63	12.50	4.08
	Fish Creek	2,400		21	101,000	449.00	21.40	4.44
	Bass Lake, Batterson	10,000		83	19,000	275.50	14.50	3.32
	Soquel	1,575		25	50,000	247.00	9.88	4.94
	Cascadel	4,800		18	26,000	150.00	7.22	5.00
	Total	35,735		392	947,000	4,183.13		

*No data; work by CCC and NIRA

Tabulation of Bark Beetle Control (continued)

Year	Project	Acreage	Spp.	Amount treated Trees	Amount treated Volume b.f.	Costs Total	Costs per tree	Costs per Mbm
1941	Shaver Lake - Big Creek	12,200		226	241,980	2,088.08	12.66	5.71
	Northfork - Bass Lake	2,220		44	9,500	105.30	2.39	11.08
	Ross Creek - Hooker's Creek	6,400		17	36,420	150.75	8.87	4.14
	Total	20,820		287	287,900	2,344.13		
1942	Shaver Lake	12,000		185	443,690		11.53	4.81
	GRAND TOTALS	619,229		19,778*	29361,352*	$103,373.89		

*Represents all species; in reports these have been separated as:

Spp.	Trees	Volume b.f.
PP	5,291	7,685,050
SP	1,052	5,634,840
Not separated but mostly PP	13,435	16,041,462

II. CHARACTER OF BEETLE INFESTATIONS IN THE SIERRA PINE STANDS

by
G. R. Struble

On the Sierra we are dealing with site and growth conditions that characterize the western slopes of the Sierra Nevada mountains. Here the growth rate of pine and the yield of wood per acre is high when compared with the eastside pine stands in northern California where growth rate is slow. While a great deal of research has led to a better understanding of bark beetle problems in eastside ponderosa pine stands, the problem in westside stands presents a more complex ecology, and such studies as have been made do not adequately explain all phases of the behavior of bark beetle infestations.

Just how much of an insight into the nature of the bark beetle problem in westside stands has been acquired? Certainly the main outlines have been brought into perspective. We know what insects are involved and their general biology has been worked out. However, only a preliminary understanding has been acquired of natural forces that motivate the rise and fall of beetle populations and of the reasons for the selection of certain trees for attack.

Types of Westside Infestations

The bark beetle infestations in the westside pine stands group into two broad types when considered from both biological and economic standpoints. These are (1) the western pine beetle in ponderosa pine and (2) the mountain pine beetle in sugar pine. Both of these insect species are aided at times by other insects, which may even dominate the infestation picture for brief periods; but in the long run it is the sustained aggressiveness of the two Dendroctonus beetles that determines the seriousness of the timber losses.

The western pine beetle - ponderosa pine type

Two species of beetles are often found associated with the western pine beetle; i.e. the pine engraver beetle, Ips confusus, and the pine flathead, Melanophila californica. Generally, this association occurs in the top portion of boles ten inches or less in diameter. Ips is by far the most common species, and when aggressive it initiates attacks in advance of the western pine beetle. The flathead is much less common and is found only in very slow growing or weakened trees. At times various combinations of all three species may be found.

The characteristic behavior of this type of infestation is to maintain relatively low loss levels for periods of some 5 to 10 years during which the western pine beetle is the dominating species (see Fig. 1). This condition, termed endemic, is broken at long intervals by rather sudden rises in loss volumes, which may last from 2 to 3 years. (See Plate I, Photo 1) The epidemic periods have usually been ushered in by aggressive Ips outbreaks which last for about one season and disappear as quickly as they develop, leaving the western pine beetle to carry on the infestation.

Pure western pine beetle infestations have been an important cause of timber losses, both in the lower elevation pine type where the stand is made up largely of rapid growing ponderosa pine and in the higher elevations where higher quality ponderosa pine is found in mixture with sugar pine and fir. Epidemics in the lower pine belt have been more aggressive and spectacular than at the higher elevations, but the same general cycles have occurred in both sites.

The Amount of Depletion.

Throughout good years and bad, the western pine beetle has taken a continuing toll of the more mature timber in all Sierra pine areas. Has this resulted in a net depletion of the stand? During short epidemic periods, it is pretty obvious that annual loss exceeds replacement by growth. However, during longer periods when low loss levels have prevailed, it is possible for growth to put back what was lost during the epidemics. Whether these stands are holding their own or not can be determined only by records and studies extending over a long period of time.

Some light upon this question has been provided by two studies in the lower elevation pine type at Bass Lake and Cascadel, and by three regional survey plots located in the higher elevation ponderosa-sugar pine type.

a. The Bass Lake Area. One of the areas most heavily hit by the 1930-33 epidemic was the pine type surrounding Bass Lake. This has been described by the writer in two reports (38 and 62) in 1934 and in 1940. In the latter a summary was presented of the surveys and control work in about 12 sections of pine type surrounding Bass Lake for the period from 1929 to 1939. It was estimated that (1) 35 percent and over of the stand had been killed on 1,300 acres, (2) 15 to 25 percent on 3,200 acres and (3) less than 10 percent on 3,000 acres.

Estimates of the losses during five years from 1929 to 1933 for the total area of 7,500 acres indicated that the beetles had killed between 6 and 8 million board feet (10,000 to 16,000 trees); while for the succeeding five-year period, 1934 to 1939, the kill had been between 250 and 400 thousand board feet (700 to 1,000 trees). Thus if we contrast the epidemic period with the endemic period which followed, we find a drop in the average annual loss of about 90 percent. The irregular distribution of this loss within the area and its relation to site is shown also by this study.

Photo
No. 1
(1931)

Photo
No. 2
(1935)

PLATE I

DEPLETION IN THE LOWER PONDEROSA PINE TYPE - CASCADEL BASIN

1. Upper Photo - October, 1931. Looking north into the infested Wiskey Creek drainage. These conditions represent the peak of the 1930-33 epidemic. The large group of infested trees showing in the distance to right of and slightly above broken snag is on R.S. Survey plot 7.
2. Lower Photo - October, 1935. The same area four years later after epidemic subsided. Where there were groups of infested trees in 1931, there are now openings in the stand. Most of the snags were felled by control work and fire hazard reduction crews. One group of recently infested trees can be seen in the upper right of this picture.

The heaviest losses were found on dry southern exposures and poor sites. It was largely on the marginal southern slopes that the 35 percent depletion of the stand occurred. The lighter losses of less than 10 percent occurred mainly on the northern exposures where the better sites prevailed.

b. The Cascadel Tree Selection Plot. The study made here was much more detailed and inclusive. It provides the only data available on the relation of beetle losses and growth replacement.

In 1926 Person set up an 80-acre plot in the lower ponderosa pine type of the Cascadel basin to study the rate of loss and the type of tree selected for attack by the western pine beetle. All trees 12 inches d.b.h. and over were measured and described by crown characters. The growth rate was determined also in the initial inventory of the plot. An annual loss record was then maintained up until the close of the 1940 season.

Person's original plan was followed up by the writer after 1931. A re-inventory of the plot was made in 1941 and a final analysis of the data accumulated during the 14-year period of study was submitted in a report "The Cascadel Tree Selection Plot, a Study of Tree Selection by the Western Pine Beetle" which was issued April 10, 1942 (68). The more significant points established in this report are as follows.

1. There was a net depletion of 10 percent of the stand volume during the period from 1926 to 1940.

   When this plot was re-inventoried in 1941, it was found that the beetles had killed by volume 28 percent of the stand originally marked by Person. Yet in spite of this loss, there were actually more trees of merchantable size on the plot than when it was measured in 1926. This can best be shown by the following summarization.

   a. Living trees (12 inches and over d.b.h.) measured by Person in 1926 1,389
   b. Trees killed by beetles, 1926-1940 226
   c. Trees of original stand surviving in 1941. 1,163
   d. New trees reaching merchantable size since 1926. . . 403
   e. Total number of trees measured in 1941 1,566

These figures appear to indicate a net gain in the stand during this period until we consider what happened to the volume. The record shows that there was:

   a. An original green stand volume in 1926 of. . . . 1,088,360 bd.ft.
   b. Killed by beetles, 1926 to 1940. . . . . 269,460 bd.ft.
   c. The original volume in the surviving trees . . . 818,900 bd.ft.
   d. Plus the estimated growth increment, 1926-40 . . 110,300 bd.ft.

e. Making a total volume in surviving trees, 1940, of . 929,200 bd.ft.
f. Plus volume of 403 new trees coming into merchantable size since 1926. . . . . 58,560 bd.ft.
g. Therefore the total green volume in the 1941 inventory is. . . . . 987,760 bd.ft.
h. The net depletion, 1926-1940 ("e" minus "g") is. . . 100,600 bd.ft. or approximately 10 percent.

It is obvious that this 10 percent net loss in volume during the 14-year period of records against an actual gain of 10 percent in the number of trees can be explained by the fact that the beetles were selecting the larger more mature trees which contain the bulk of the merchantable volume. It will require still more time for the younger trees to make up the volume that has been lost - a condition that will ultimately be accomplished unless another epidemic occurs to upset the replacement that has been taking place during more recent years.

2. Trees of slow growth rate are selected for attack in preference to fast growing trees.

The most susceptible trees were found to be those making less than 1.00 millimeter average annual radial growth over a ten-year period. (33 percent of the total number of trees killed on the plot were in this growth category.) Trees showing a growth rate above 1.00 mm per year are attacked with less frequency, and no trees which have maintained a growth rate of 5.00 mm per year over a ten-year period were found to have been attacked. (Trees occurring in this growth cateogory comprised only 2 percent of the stand however.)

It was also found that a sudden lowering or rise in current growth rate for a period of two years or longer may be followed by increased or decreased insect kill. This preference for slow growing trees was strongest during the periods of endemic infestations. During the peak of the epidemic, a considerable percentage of the trees that were attacked and killed were fast growing, or above the one millimeter annual average.

3. There was a definite preference for trees in the diameter classes ranging from 24 to 34 inches d.b.h. Selection by diameter was considered only on an empirical basis. It may be explained by the slowing down in growth rate of trees as they come into these diameters and approach maturity.

c. Regional Survey Plots 9, 12 and 14. These three plots of 320 acres each which were set up in 1930 provide the longest continuous loss record in the better quality ponderosa type. The plots are located in the Chiquito Basin (No. 9), Fence Meadow (No. 12) and Aspen Valley - Yosemite N. P. (No. 14). The data for the 10-year period, 1930-39 are summarized in the following table.

Ponderosa Pine Losses on Regional Survey Plots from 1930 to 1939

Ponderosa Pine Green Stand, 1930*	Plot No. 9 Chiquito	Plot No. 12 Fence Meadow	Plot No. 14 Aspen Valley
Trees	4,500	4,130	6,570
Volume	5,667,000 b.f.	5,391,000 b.f.	7,446,000 b.f.
Beetle-kill, 1930-39			
Trees	197	683	240
Volume	304,330 b.f.	1,273,160 b.f.	407,890 b.f.
Volume per acre	951	3,978.6	1,274.6
Percent of original stand killed.			
Trees	4%	17%	4%
Volume	5%	24%	5%

*Based on 10 percent cruise

Without a growth study it is not possible to determine whether or not appreciable depletion occurred on these plots during this period. On plots 9 and 14 the percent of the stand killed during this period averages one half of one percent by volume, which may indicate that loss and growth have just about balanced. On plot 12 the average annual loss by volume is 2.4 percent annually, which is considerably more than the replacement to be expected from growth increment.

Effects of Bark Beetle Infestations in the Ponderosa Pine Type.

In the overall appraisal of depletion in ponderosa pine, it can be said that in the more favored sites, some stands are holding their volume, regardless of periodic beetle epidemics. In the less favorable sites where the beetles have hit the hardest, there has been a measurable depletion of timber volume. (See Plate I, Photo 2) The greatest part of the loss, however, has occurred in the old growth trees representing the best commercial values; on the other hand, replacement for the greater part is made up by the growth in younger trees which still have many years to grow before they reach the maximum merchantable quality. Under any short term logging expectations, the depletion by beetle kill is of more consequence than the percentage figures indicate.

The Mountain pine beetle - sugar pine type

The mountain pine beetle attacks the main bole of sugar pine from a few feet above the ground to within a few feet of the top, and often the basal parts of the large branches. As a rule it attacks the large mature trees in the top first, with later infestations occurring progressively toward the base. Poles and small to medium-sized merchantable sugar pines are infested generally at one time by concerted attacks.

Other insects associated with the mountain pine beetle are the pine engraver beetle, Ips confusus Lec., and the flathead borer Melanophila gentilis Lec. Extensive top-killing and lateral branch killing by Ips is common, particularly during epidemic periods. Primary flathead killing rarely extends over the entire bole, but remains confined within limits along any portion from top to bottom. Neither of these insects compares in importance to the mountain pine beetle which can be cited as the primary cause of death of sugar pines in the great majority of cases.

Records of the insect control projects undertaken on the Sierra National Forest show that within the past thirty years, there have been three major periods when the mountain pine beetle was aggressive generally. The peaks appear to have been in 1917, 1924 and 1932. (See Plate II, Photo 1) In between the epidemic periods there have been localized or sporadic infestations occurring at different times. In 1937, for example, there was an outbreak in the cutover reserve stand at Signal Peak (Struble - 54). In 1937 heavy localized attacks were found in Mariposa Grove in Yosemite National Park. In 1941 there was a sudden increase in infested trees in the Shaver Lake-Big Creek area. Infestations of this type were in most cases traceable to previous windfall damage.

Preliminary studies have shown that trees selected by the mountain pine beetle have varied extremely in age and crown characters. There has been no apparent preference indicated among varying age groups and among different conditions of the crown from vigorous to very decadent, although the incidence of old, overmature trees killed seemed to be very high. This apparent lack in selection has so far baffled all efforts of forest entomologists to find a clue to the reasons for it.

Entomological research studies initiated at the time of the epidemic and which are still in progress have revealed that (1) growth rate has no apparent relation to selection, (2) crown characters offer no significant clue to selection, (3) site conditions offer some possibilities since there is indication that losses tend to continue year after year in local areas having certain site characteristics. There is still much more research work to be done on this problem before adequate control of the beetle is possible.

The Amount of Depletion.

The ten-year record of losses from 1930 to 1939, inclusive, on Regional Survey plots 9, 12 and 14 in typical ponderosa pine-sugar pine type will suffice to illustrate the approximate amount of depletion that has taken place. The comparative depletion of the sugar pine stands on these plots is tabulated on page 30 for the ten-year period, and represents probably the maximum condition of loss for any ten-year period, inasmuch as the worst epidemic on record occurred during this time.

The exceptionally heavy losses sustained on the Fence Meadow plot, which is representative of the sugar pine-ponderosa pine type in the Kings River area are of special interest. Why the kill was heavier than in

Photo No. 1

PLATE II

DEPLETION IN THE PONDEROSA - SUGAR PINE - FIR TYPE

1. Area west of Mariposa Big Tree Grove in 1932. The white tops are mostly sugar pines infested by the mountain pine beetle; several ponderosa pines at left are infested by the western pine beetle. Bark beetle infestations in this type tend to occur in single trees and small groups rather than in large groups of infested trees.

2. Sugar pine snags along the Bass Lake-Beasore road. Although mountain pine beetle infestations in sugar pine are not as spectacular as western pine beetle in ponderosa pine during epidemics, the cumulative loss of large valuable trees is almost equally formidable. On the Fence Meadow Plot, for example, the loss in sugar pine volume from 1930-39 amounted to 21 percent of the volume, or 1,505 board feet per acre. The openings in the stand created by death to these large trees is replaced quickly by dense fir reproduction.

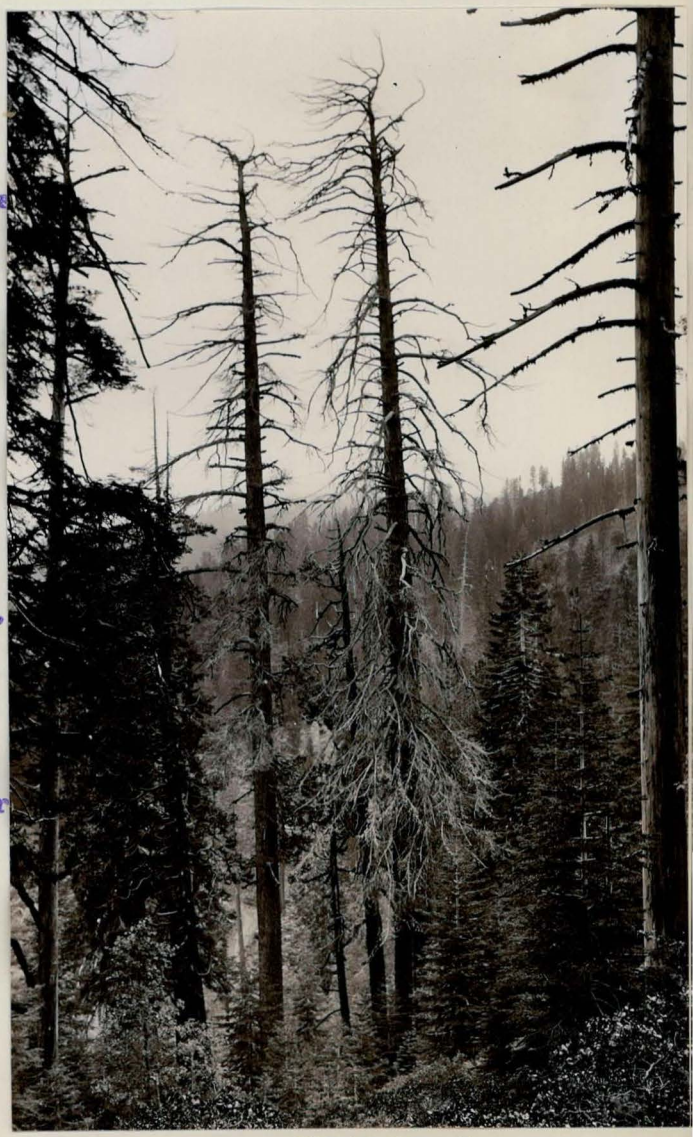


Photo No. 2

the Aspen Valley plot which is more heavily stocked with all species is difficult to explain in the absence of more data. There can be little doubt, however, that the hazard from whatever cause was greater here than on the other two plots compared.

Sugar Pine Depletion on Plots RS 9, 12 and 14 from 1930 to 1939, Incl.

Sugar Pine Green Stand, 1930*	Plot No. 9 Chiquito	Plot No. 12 Fence Meadow	Plot No. 14 Aspen Valley
Trees	960	1,240	1,130
Volume	1,437,300 b.f.	2,255,600 b.f.	3,635,400 b.f.
Beetle-kill, 1930-39			
Trees	54	130	57
Volume	137,770 b.f.	481,570 b.f.	362,250 b.f.
Volume per acre	430.5	1,504.9	1,132.0
Percent of original stand killed.			
Trees	6%	10%	5%
Volume	10%	21%	10%

*Based on 10 percent cruise

Effects of Depletion in the Sugar Pine Type.

A comparison of the sugar pine and ponderosa pine depletion on these same plots shows that on plots 9 and 14 the percent of sugar pine volume killed annually has averaged one percent or just twice that of the ponderosa pine. On RS-12, the average annual loss of sugar pine has been 2.1 percent as against 2.4 percent for ponderosa pine. Little is known of the sugar pine growth increment, but it has been a matter of observation that as the large mature trees are killed out by beetles, restocking by young sugar pine is quite unsatisfactory. Usually the openings are captured by fir reproduction rather than sugar pine. (See Plate II, Photo 2) Obviously all three plots show a net depletion for the ten-year period, since there is little chance of growth replacing losses averaging above 1 percent. Economically this loss of the mature sugar pine which is not replaced is the most important phase of the mountain pine beetle problem calling for a solution. It can be prevented only by direct control or by management practices which will utilize the old crop of sugar pines before they are killed by beetles.

III. SOME PROBABLE CAUSES OF BARK BEETLE EPIDEMICS ON THE SIERRA

by
Ralph C. Hall

One characteristic of the beetle-caused loss record in the pine type of the Sierra is the irregularity of the annual kill, although there is some indication of a cyclic tendency during certain periods. If we look at the graphic representation of the losses from 1912 to 1942 in Figure 1, we find long periods of low loss levels, below 200 board feet per acre, interrupted by very brief periods when the loss rose above this level. Most striking of all are the years 1930-32 when the loss rose sharply to a point in excess of ten times the average for the preceding 19 years.

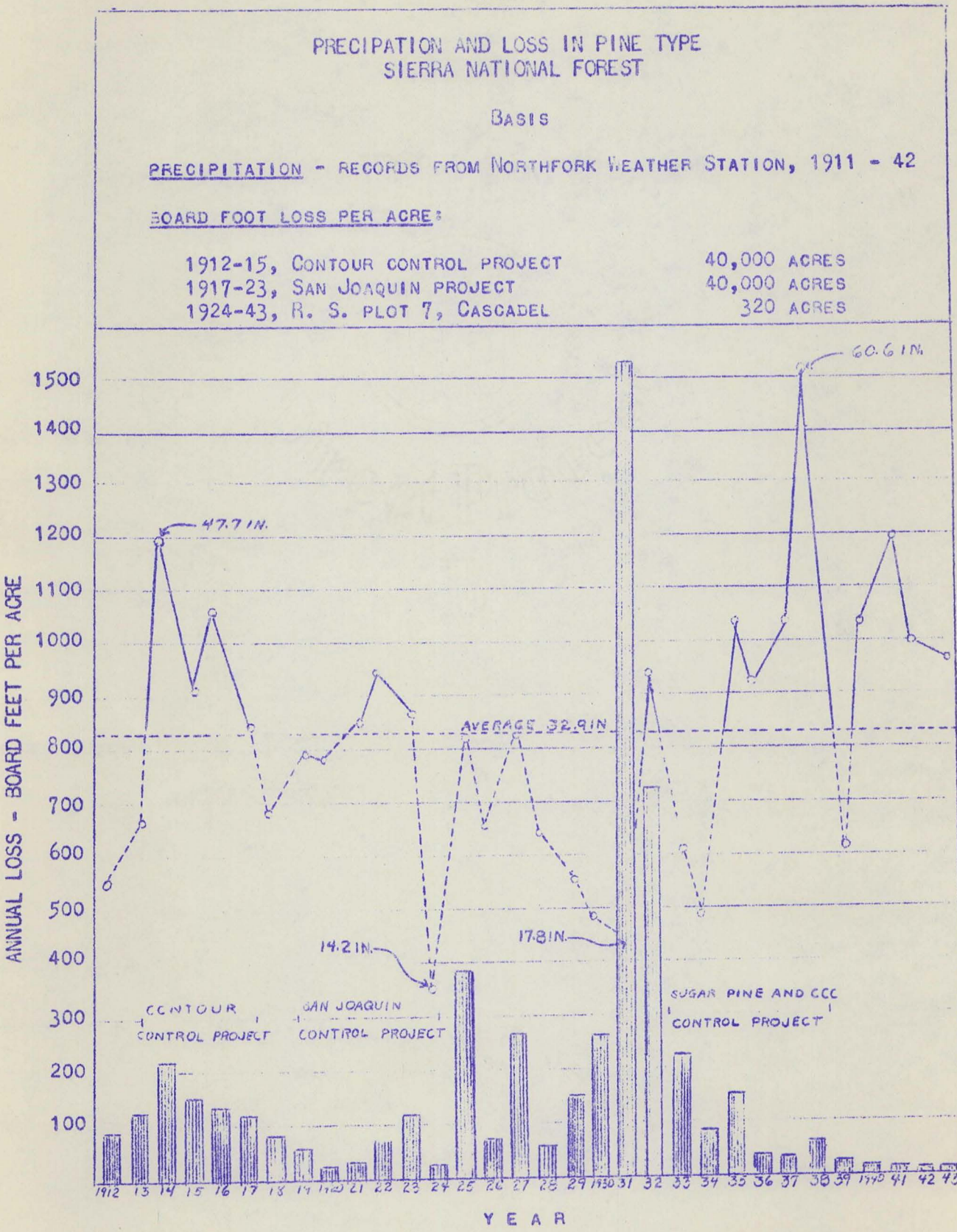
It must be assumed that these fluctuations in the amount of pine killed annually reflect sporadic changes in bark beetle population; i.e. when pine losses are high there is a corresponding increase in beetles. The insect data recorded from thousands of infested trees on surveys and control projects have established that bark beetle populations are abundant in high loss years, and are correspondingly light in low loss years. There is no evidence to indicate that these insect populations can maintain themselves anywhere except in the trees where they attack and develop successful broods.

The causes of these sporadic outbreaks of beetle populations and the accompanying timber losses have been the subject of much speculation and various attempts have been made to explain them by plausible but unproven theories. The more common explanations that have been offered can be loosely termed: (1) the climatic theory, (2) the light burning theory and (3) the biological cycle. We will discuss these only in their general aspects to see how they can be applied to the Sierra record. Although the ideas involved are too closely interrelated to designate them as three separate theories, this breakdown serves as a convenient approach to the problem.

1. The Climatic Theory

There has long been a general belief among those interested in this problem that bark beetle outbreaks are directly related to drought periods. When the dry years come, the trees are set back in growth because of lack of soil moisture and the beetles then take advantage of this weakened condition to attack and multiply in numbers. This goes on until the wet years come and the trees recover their growth rate and resistance. During these years of good growth, it requires more beetles to successfully attack vigorous trees, many are "drowned out" by pitch flow and, in those trees that are finally overcome, the broods do not develop as prolifically as they do in weakened trees.

FIGURE 1


PRECIPATION AND LOSS IN PINE TYPE
SIERRA NATIONAL FOREST
BASIS
PRECIPITATION - RECORDS FROM NORTHFORK WEATHER STATION, 1911 - 42
BOARD FOOT LOSS PER ACRE:
1912-15, CONTOUR CONTROL PROJECT 40,000 ACRES
1917-23, SAN JOAQUIN PROJECT 40,000 ACRES
1924-43, R. S. PLOT 7, CASCADEL 320 ACRES
ANNUAL LOSS - BOARD FEET PER ACRE
SEASONAL PRECIPITATION IN INCHES
YEAR
47.7 IN.
60.6 IN.
AVERAGE 32.9 IN
14.2 IN.
17.8 IN.
CONTOUR CONTROL PROJECT
SAN JOAQUIN CONTROL PROJECT
SUGAR PINE AND CCC CONTROL PROJECT

This theory places most of the emphasis on precipitation and we find that the known rainfall history of the Sierra shows wide fluctuations in seasonal amounts. According to such historical data as are available, there were drought years in 1877 and 1899 before the Northfork weather station was established. These years are known to have worked hardships upon stock dependent upon the San Joaquin ranges, but it seems that no one noted or little cared what the beetles were doing then. If any epidemics occurred, the evidence had long since disappeared by the time that foresters began to regard the dying of pine trees as a matter of concern.

Beginning in 1912 we have an annual record of beetle-caused losses to go along with the record of annual precipitation of the Northfork Station, which lends some support to the climatic theory. Up until 1918 the loss record is made up from the timber treated on control projects, which cannot be regarded as entirely accurate when transposed into annual board foot loss per acre, but these records are considered to be quite reliable in reflecting the loss trends of these years. Since 1918 the total annual losses were measured on sample plots and specific areas.

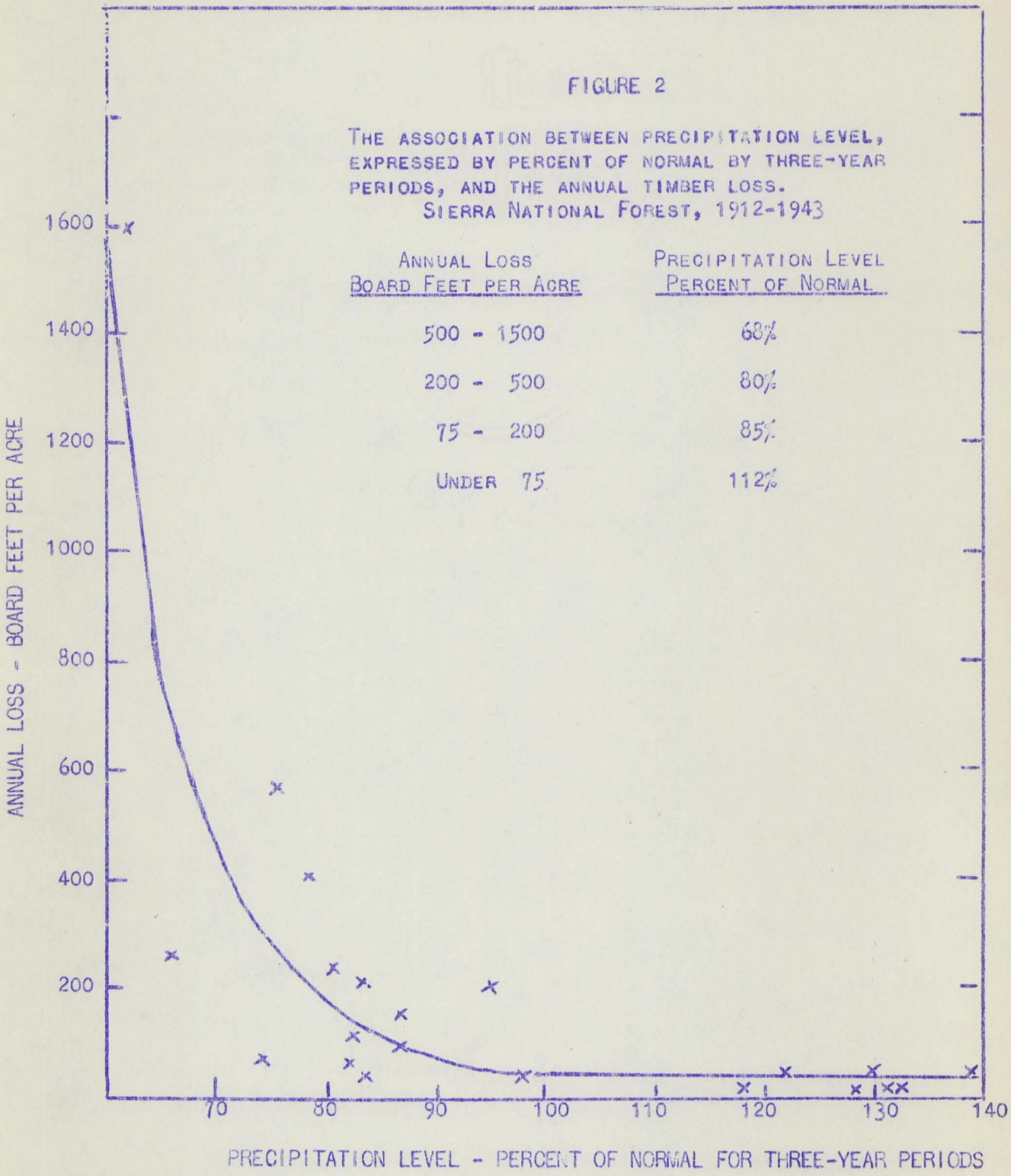
In comparing the loss trend in the Sierra with the precipitation trend from the Northfork weather records (Figure 1) certain broad associations are evident. We find for example that the heavy loss of over 1500 board feet per acre in 1931 was preceded by below normal precipitation in 11 of the preceding 15 years, with one continuous period of eight years, when the precipitation was below normal; and for two of these years the precipitation was only about 50 percent of normal. One characteristic of the association between precipitation and loss is that it is not specific in all years; i.e. a drought year does not necessarily mean a heavy loss year, as may be noted for the years 1912, 1924, 1934 and 1939. Neither does the above normal precipitation mean low loss as may be noted for the years 1914, 1932 and 1935. In studying these data it appears that precipitation effects are cumulative, either favorable or unfavorable and that precipitation effects in any one year are dependent to a large extent on precipitation for at least two years previously. This is shown in Figure 2 where the percent of normal precipitation for each three-year period is plotted against annual loss. Although considerable variation exists in this series, it does show a rather marked association between these two factors and is particularly striking when loss is grouped in broad categories. For example, when the loss ranged from 500 to 1500 board feet per acre, the average precipitation level for the previous three years averaged only 60 percent of normal; from 200 to 500 board feet the precipitation was 80 percent; from 75 to 200 it was 85 percent; and below 75 board feet the average was 112 percent of normal.

Precipitation and tree growth. Although it can be shown that there is an apparent relation between precipitation and beetle populations as represented by pine losses, it must be conceded that the relationship is not a direct one. Obviously dry weather in itself does not generate beetles spontaneously - drought first must have an effect upon the trees which creates conditions favorable for the beetles to multiply in.

FIGURE 2

THE ASSOCIATION BETWEEN PRECIPITATION LEVEL, EXPRESSED BY PERCENT OF NORMAL BY THREE-YEAR PERIODS, AND THE ANNUAL TIMBER LOSS.
SIERRA NATIONAL FOREST, 1912-1943

ANNUAL LOSS BOARD FEET PER ACRE	PRECIPITATION LEVEL PERCENT OF NORMAL
500 - 1500	68%
200 - 500	80%
75 - 200	85%
UNDER 75	112%

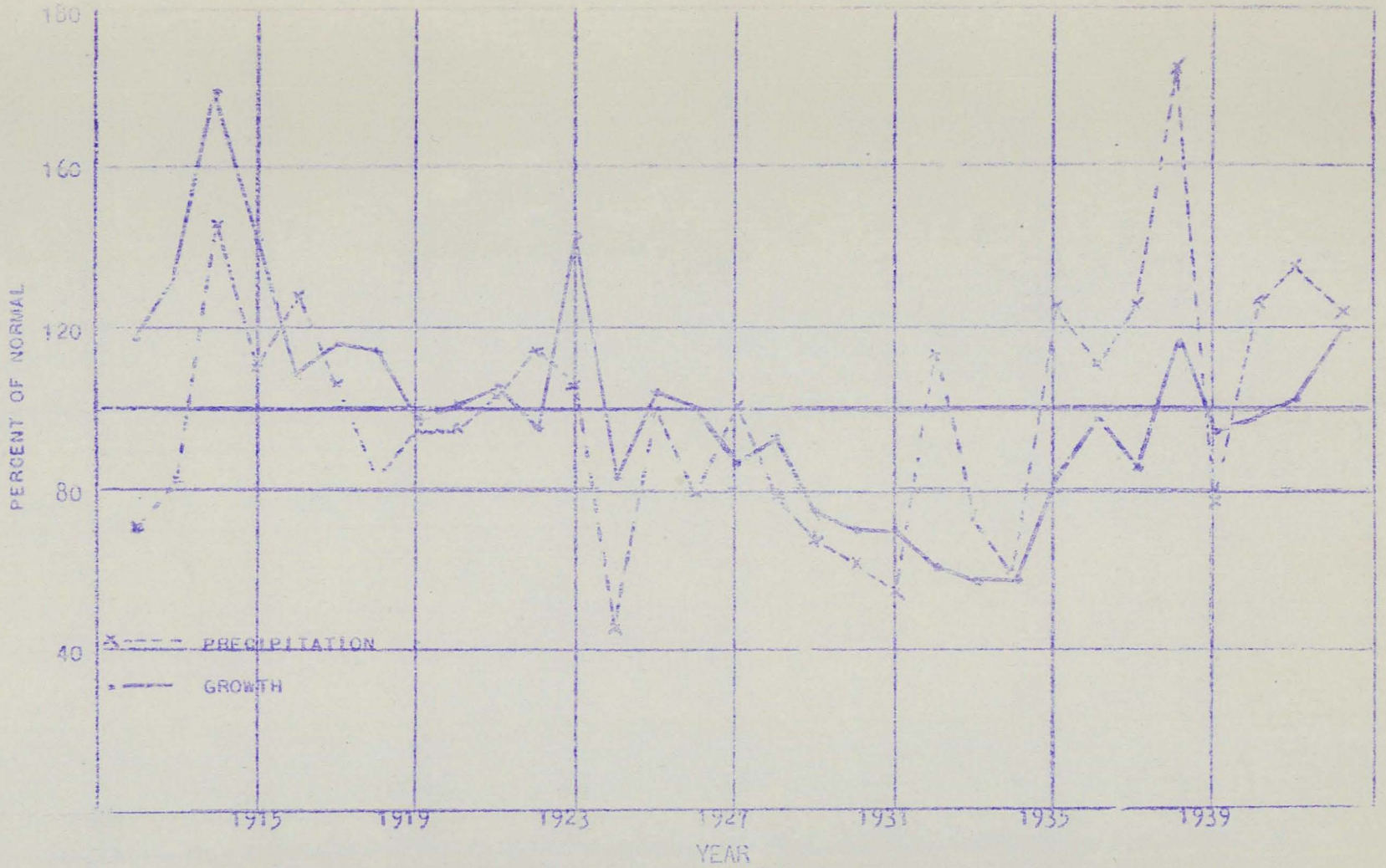


This we can be sure must come through the growth reactions of the trees to periods of deficient or abundant precipitation. A comparison of tree growth and precipitation as represented by the average growth pattern of a series of selected trees from the Cascadel basin and the Northfork weather record for the period 1912-42 is shown in Figure 3. While these data indicate a very marked association, the effect of precipitation on growth appears to differ in different periods; and here again, as in the loss picture, the precipitation affect in any one year seems to be dependent upon precipitation in the preceding years. From 1912 to 1923, inclusive, growth was above normal for ten years and below normal for two years; precipitation was above normal for seven years and below normal for five; but in no case was precipitation seriously below normal.

From 1923 to 1942 growth was below normal for fifteen years and slightly above for four (1925-38-41-42), while precipitation was below normal for 11 years and above for 8. The above normal precipitation for 1932 followed eight years when precipitation had been below normal and appears to have had no effect in changing the growth trend which still progressed downward in 1933. These data seem to show that the prolonged drought from 1924 to 1931 was a serious shock to the trees and that recovery after this drought was comparatively slow. From 1912 to 1931 the precipitation percent of normal was below the growth percent of normal in 17 out of 20 years; after 1931, however, the precipitation curve was above the growth curve in 10 out of 11 years. The different effects of precipitation by different periods is further illustrated in Figure 4. Note that during the first 15-year period all the years except 1916 and 1922 fall below the equality line.

Tree growth and losses (beetle populations). In 1940 Struble (68) made an analysis of the Cascadel tree selection plot in which he compared the growth rate of 10 percent of the trees with the losses on the plot for the period 1923 to 1940, inclusive. This comparison, illustrated in Figure 5, shows a steadily declining growth rate over a period of several years prior to 1930 which was followed by a very rapid rise in the loss level; on the other hand, the general rise in growth rate from 1934 to 1940 was accompanied by a fluctuating but never the less substantial lowering of the loss level. In general it can be claimed that beetle-caused losses are inversely related to the growth rate. This conclusion is supported by other studies that have been made on the Sierra, mainly by Person (27 and 28) and Struble (68) who have shown that as a rule the beetles select the slower growing trees in the stand and that the more vigorous trees escape.

On the whole, the climatic theory does seem to have much in its favor. However, it cannot be considered in itself as the one answer to the question of what regulates beetle abundance. The problem breaks down into many phases and there are numerous other factors which have a direct effect upon beetle populations other than climate. Some of these factors will be considered under the biological theory.



THE NORMAL TREND IN PRECIPITATION AND GROWTH FOR THE PERIOD 1912 TO 1942, EXPRESSED AS PERCENT OF NORMAL. (NORTHFORK PRECIPITATION RECORD AND GROWTH AVERAGE OF SELECTED TREES, CASCADEL BASIN, SIERRA NATIONAL FOREST)

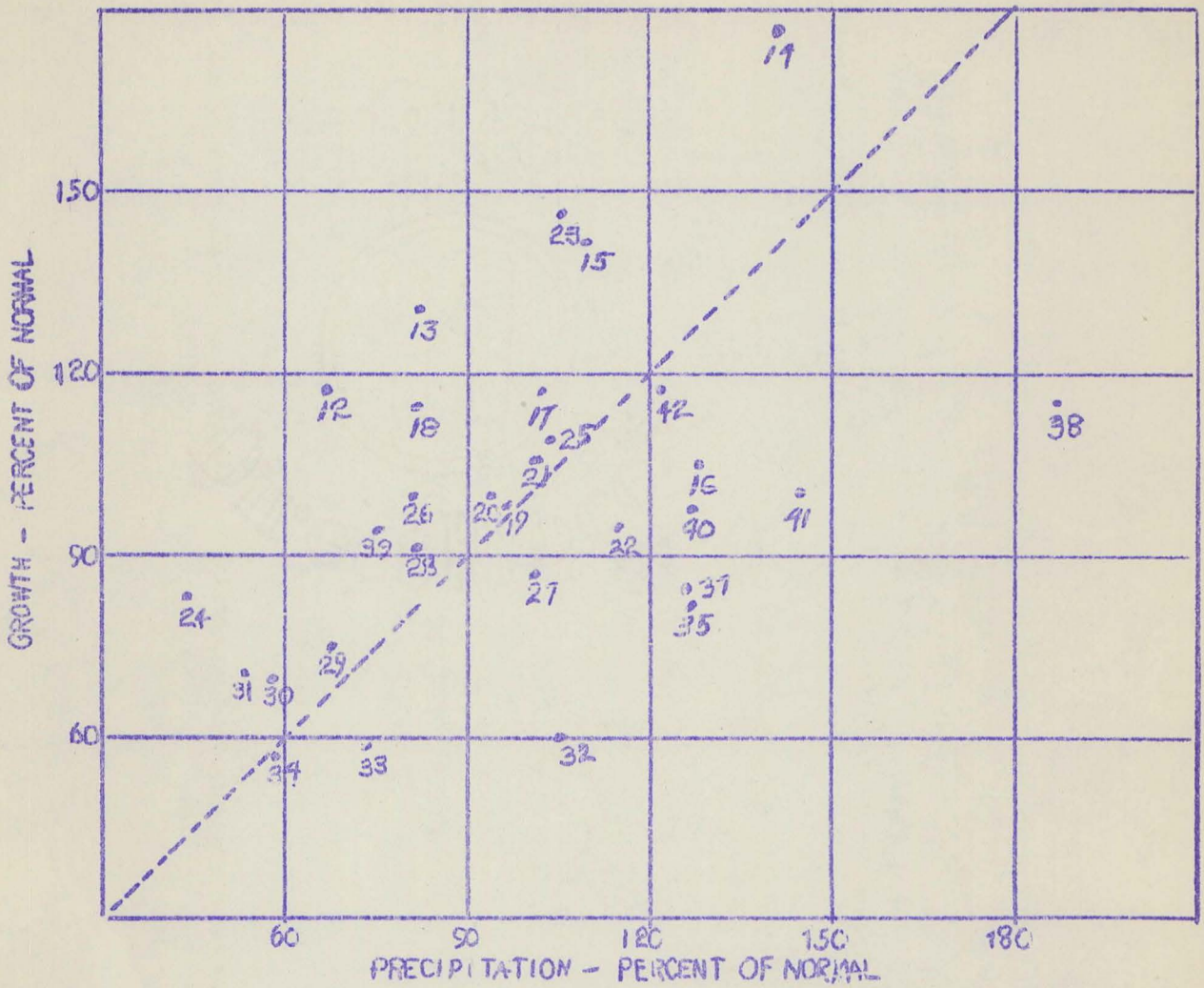
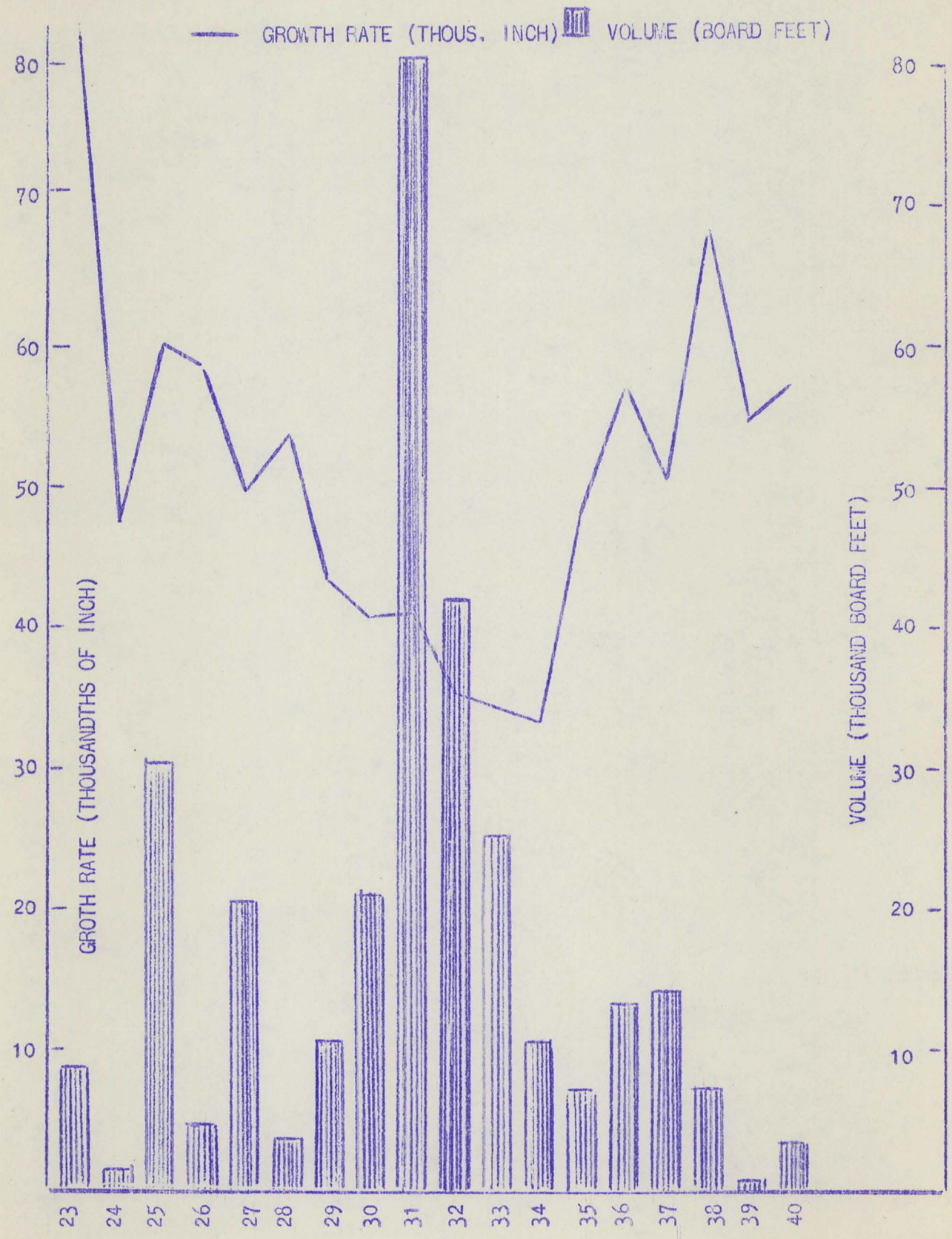


FIGURE 4

PRECIPITATION PERCENT OF NORMAL, PLOTTED AGAINST GROWTH PERCENT OF NORMAL FOR THE PERIOD 1912 TO 1942. (NORTHFORK PRECIPITATION RECORD AND GROWTH AVERAGE OF SELECTED TREES, CASCADEL BASIN, SIERRA NATIONAL FOREST)

FIGURE 5. CASCADEL TREE SELECTION PLOT

GROWTH RATE OF 10 PERCENT SAMPLE OF ORIGINAL GREEN STAND, 1923-40, COMPARED WITH VOLUME OF TREES KILLED BY INSECTS DURING THIS PERIOD.



2. The Light Burning Theory

The theory that forest fires of a certain character have a controlling effect upon bark beetles has been advocated by some and damned by others without much supporting evidence on either side. Although the idea seems to have originated with the old residents of the region whose stock was dependent on forage in the brush and pine types, the theory has been advocated by no less an author than Stewart Edward White representing the White and Friant Lumber Company. It has also been supported by responsible stockmen's associations. The theory has been almost universally opposed by foresters as unsound protection policy. However, it is only the bark beetle phase of the light burning theory that we are concerned with here.

Direct effect of fires on beetle populations. The advocates of light burning originally believed that light ground fires destroyed the pine beetles. As advocated by Mr. White (6 and 9), these insects breed in the ground litter and debris of the forest floor, or at least harbor there, so that when this is burned beetle populations are destroyed. It was even suggested that the smoke of the fires killed them in flight or drove them out of the woods. Biological studies by entomologists have shown little basis for these ideas. Bark beetles breed only in living or dying trees, and for most of their existence are protected by the insulation of the bark, so that there is little possibility of their being affected by light fires. It has been found that even severe crown fires very rarely kill the broods in infested trees. That beetles in flight might be caught in going fires is largely accidental and could have little effect upon total populations.

Indirect effect of fires. A study that was made of the Northfork burn of 1924 (Miller 30 and 69) throws considerable light upon what takes place on burns in the pine type following fires. The reports of this study show that for two seasons following the fire, heavy bark beetle infestations concentrated within the burned area, killing about 20 percent of the pine stand that had survived the fire. Practically all of this infestation was found in trees which had been fire injured (25 to 100 percent of crown defoliated). By the third season after the fire, infestations within the burn had subsided to a subnormal condition. Very light beetle infestations developed within the burn during the period from 1928 to 1942, although the heavy epidemics of 1930-32 developed in the nearby stands, particularly in the unburned Cascadel basin.

It was found that during the period of high losses within the burn, the distribution of the infestation was directly related to the degree of fire injury to the crowns. Scarcely any beetle attacks were found in areas where the fire had burned lightly and the crowns of the trees were uninjured; but where the fire had been severe and scorched the crowns of a high percent of the trees, the infestation was concentrated and most of the more heavily injured trees were killed. The degree of fire injury therefore largely determined the location and amount of bark beetle infestation following the fire.

The Northfork burn study indicates that fires of the more severe type do create temporary conditions that are highly favorable to the multiplication of beetle populations, but on this burn the infestation did not spread aggressively into unburned pine stands around the burned areas; the beetle populations subsided when the supply of fire-weakened trees was exhausted. Therefore, the fire could not have had any great effect upon the general cycle of infestations outside of the burn. However, this result apparently does not follow in all cases since observations on a few other burns have indicated that some of the infestation, developing as a result of the fire, moved into adjoining areas. Fire injury, like slash, appears to combine with other factors when aggressive infestations follow.

Beetle hazards on burned areas over long periods. Another phase of the light burning theory is that occasional light fires which keep down the brush and other ground cover create conditions which are unfavorable to bark beetle populations in mature pine stands. This has not been established by supporting evidence which can be accepted as conclusive, but on the other hand this phase of the theory cannot be dismissed. Recent studies in other regions of the ponderosa pine type have indicated that the amount of understory in mature pine stands does have some bearing upon the susceptibility of the trees to pine beetle attack. An analysis of the factors involved in area hazard to bark beetle infestations in the Klamath Basin of Southern Oregon brought to light the fact that the amount of brush and reproduction in stands of mature pine gave the best correlation with the incidence of bark beetle infestations. This can be explained when we consider that this younger growth depletes the soil moisture and is in competition with the older trees. In the end the effect on the growth of the old trees is similar to that of drought. Something like this seems to have occurred in the Pinchot Grove of sugar pines near Ellis Meadow where in 1929-32 a number of the large mature trees were killed by the mountain pine beetle after the ground cover in the grove had been taken over by heavy white fir reproduction. According to the light burning idea, light fires which would have cleaned out the fir might have saved the sugar pines.

The best that can be said for the elimination of undergrowth is that it may involve a principal of hazard reduction which should be given consideration in the protection and management of some pine stands to prevent beetle losses. That fire is the method with which to eliminate the competition of an undesirable understory is questionable. Here again the weight of other factors must be considered and further study is needed before conclusions are warranted. So far the weight of evidence, as pointed out and illustrated by Miller (69) in the Northfork burn study, supports the conclusion that the fire-bark beetle combination has operated to push back the lower pine belt to higher elevations; and, in this recession of pine type the more marginal sites have been captured by brush cover.

3. The Biological Cycle

The idea that bark beetle populations fluctuate with a certain degree of cyclic rhythm or periodicity due to the operation of biological factors is entitled to consideration. The theory has found some support in the case of other insects. The writer has pointed out that there is an apparent periodicity of about seven years in the loss records of the eastside pine type. In the Sierra record the data appear to show a tendency toward a nine-year cycle. It can be noted that beginning in 1912, three cycles are discernible, 1912 to 1920, with the peak year in 1914; 1920 to 1928, with the peak year in 1925; and 1928 to 1937, with the peak year in 1931. Certain years are seen to fall out of line in these last two periods, such as the low loss years of 1924, 1926 and 1934; but other years conform to the expected trends. These departures could very well be attributed to sampling error as the basis of one 320-acre plot maintained during these periods would tend toward error during low loss years. Since 1938 the general loss level has been so low that the sampling error may be great enough to obscure any cyclic trends.

Whether or not these are true cycles cannot be claimed until the factors underlying changes in population density can be assessed for their true value. The factors to be considered are those which operate directly upon the beetles rather than upon the host tree. These include the following:

Temperature. Temperatures affect the beetle in two ways.

The rate of brood development during the active season is retarded or accelerated by periods of cool or warm weather. It has been found that below normal temperatures during the developmental period of the beetles may make a difference of between a partial and a complete generation loss in a single season. Because of the longer season in the westside climate of the southern Sierras, the western pine beetle produces each season almost a complete generation more than it does in the colder climates of northeastern California.

Extreme low winter temperatures kill the overwintering broods. Sub-zero temperatures in northeastern California have been quite effective in killing broods at times, but there is little evidence that this factor has caused any appreciable mortality on the Sierra, aside from one record of a slight amount of winter kill near Bass Lake in 1934.

Predators.

Insects which prey upon pine beetles are always present wherever these infestations occur. Person made a detailed study of the biology of the Clerid beetle on the Northfork areas and although it was found to be an effective predator on all stages of the western pine beetle, no method was found by which to assess its total effect upon the infestation for any particular area or season. The same is true of the effectiveness of certain woodpeckers which feed upon overwintering bark beetle broods. Obviously this natural predation is at times important in limiting bark beetle populations, but to just what extent or at what times cannot be measured.

Artificial control work.

This is a man-made factor that operates directly on the beetles, and it cannot be disregarded in analyzing the Sierra record. Since 1912 control work has been undertaken whenever the infestation became particularly aggressive, and this undoubtedly destroyed enormous numbers of beetles and many of their natural predators along with them. It is only reasonable to assume that the epidemics would have reached higher peaks and would have been of longer duration had it not been for this work. In this respect control work may have obscured or upset the natural cycle of the infestation. The only time that the beetles appear to have gotten entirely out of hand was in 1930-31 following the six-year period after 1924 when no control was done.

Slash and windfalls.

Although not a direct factor, slash and windfalls have been known to give an impetus to bark beetle infestations. Under certain conditions these insects, particularly Ips, breed up rapidly in slash and then attack standing trees. This may have been a factor in the losses that developed in 1913-14 following the clearing of the site for the Bass Lake Reservoir when a great amount of pine slash was created. Again in 1930 the closing down of the Sugar pine sale may have released the large Ips epidemic which attacked the tops of thousands of standing green trees during the late summer of that year. The effects of these slash conditions may have been of importance in the outbreaks with which we are concerned, but it is more probable that this factor operated in combination with climatic and biological forces in its effect upon infestation trends.

4. Current Studies of Factors Affecting Bark Beetle Infestations on the Sierra Areas.

In the above discussions, no one theory has been found adequate to explain the behavior of beetle infestations in westside pine types. The weight or importance of any one factor in the problem is dependent to a large extent on the weight of other factors with which it is associated. The tendency in the past has been to study one factor intensively for a few years and then shift to another factor, dropping work on the first factor in the meantime. It would appear that the only way to get a true perspective of this complex problem is to study as many factors as possible at the same time. The main purpose of the program of research and surveys carried on by the forest insect field laboratory located at the Miami Ranger Station is to obtain a clearer understanding of westside bark beetle problems through this broad approach. This program must necessarily be restricted for the duration of the war, but it is planned to cover the general precipitation and loss effects, and to investigate the factors that enter into area hazards from bark beetle infestations.

The maintenance of some weather records in the areas and on the sites where timber losses are actually occurring is one of the requisites of these studies. Figure 6 shows the distribution of the weather stations in timbered areas which are being used in this study. There are three stations sampling the Yosemite and Miami areas (Nos. 1, 2 and 3) and three stations sampling the Chiquito basin (Nos. 4, 5 and 6). With the present limited manpower available for research, these stations can be serviced only two or three times each year. High capacity precipitation storage gauges, charged with calcium chloride and light oil, permit the trapping of precipitation either in the form of snow or rain for long periods between readings. These records, if maintained over a long period of years in conjunction with accurate quantitative loss records in the same areas, should provide the basis for further studies concerned with the appraisal of factors entering into the losses caused by bark beetles.

The results of this research program should enable us to tell when epidemics are to be expected, what measures can be taken to prevent them, and how to manage these mixed conifer stands so that beetle-caused losses will not interfere with maximum timber production.

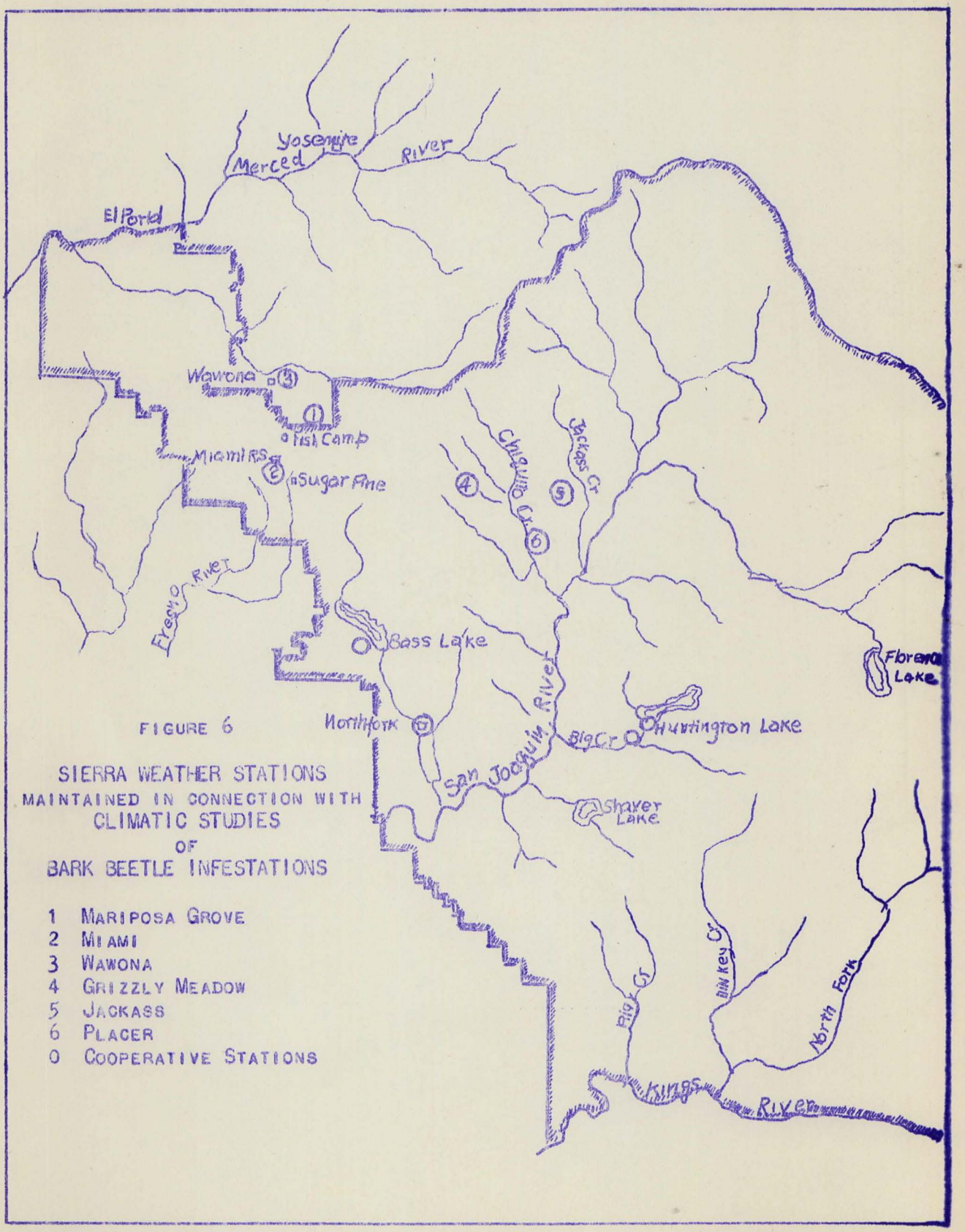


FIGURE 6

SIERRA WEATHER STATIONS
MAINTAINED IN CONNECTION WITH
CLIMATIC STUDIES
OF
BARK BEETLE INFESTATIONS

1 MARIPOSA GROVE
2 MIAMI
3 WAWONA
4 GRIZZLY MEADOW
5 JACKASS
6 PLACER
O COOPERATIVE STATIONS